Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat (CSAS)

Research Document 2015/026

Maritimes Region, Newfoundland & Labrador, and Gulf Regions

Current Status and Threats to the North Atlantic Blue Shark (*Prionace glauca*) Population in Atlantic Canada

Steven E. Campana[1], Mark Fowler[1], Dan Houlihan[1], Warren Joyce[1], Mark Showell[1], Carolyn Miri[2] and Mark Simpson[2]

[1]Population Ecology Division
Bedford Institute of Oceanography
P.O. Box 1006, Dartmouth, N.S.
B2Y 4A2

[2]Aquatic Resources Division
Northwest Atlantic Fisheries Centre
P.O. Box 5667, St. John's, NL
A1C 5X1

June 2015

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

© Her Majesty the Queen in Right of Canada, 2015
ISSN 1919-5044

Correct citation for this publication:

Campana, S.E., Fowler, M., Houlihan, D., Joyce, W., Showell, M., Miri, C., and Simpson, M. 2015. Current Status and Threats to the North Atlantic Blue Shark (*Prionace glauca*) Population in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/026. v + 44 p.

TABLE OF CONTENTS

ABSTRACT iv

RÉSUMÉ v

INTRODUCTION 1

LIFE HISTORY CHARACTERISTICS 2

- REPRODUCTION 2
- NATURAL MORTALITY 2
- AGE AND GROWTH 2

DISTRIBUTION, MIGRATION AND DESIGNATABLE UNITS 2

- DISTRIBUTION IN CATCH 3
- DISTRIBUTION AND MIGRATION FROM TAGGING STUDIES 3
- DESIGNATABLE UNITS 4

POPULATION TRENDS 4

- CATCH RATE OF BLUE SHARK IN CANADIAN WATERS 4

BLUE SHARK HABITAT 5

THREATS 5

- COMMERCIAL LANDINGS 5
- OBSERVER BYCATCH 6
- ESTIMATION OF UNOBSERVED BLUE SHARK BYCATCH 6
- HOOKING AND POST-RELEASE MORTALITY 7
- BYCATCH DISTRIBUTION 8
- RECREATIONAL SHARK FISHERY AND SHARK TOURNAMENTS (DERBIES) 8
- EXPLOITATION RATE FROM TAG-RECAPTURES 8
- TOTAL CATCH MORTALITY 9
- SUSTAINABLE MORTALITY LEVEL FOR BLUE SHARKS IN CANADIAN WATERS 10

DISCUSSION 11

ACKNOWLEDGEMENTS 12

REFERENCES 12

TABLES 15

FIGURES 27

ABSTRACT

Both conventional and satellite tagging studies indicate that blue sharks are widely distributed and highly migratory across both Atlantic Canada and the North Atlantic waters, with no evidence of year-round residency in Canadian waters.

There is no fishery-independent index of abundance for blue sharks in Canadian waters. Standardized catch rates from observers on pelagic longline vessels provide an index of local, short-term abundance, but do not appear to reflect population abundance. Population abundance in the North Atlantic appears to have decreased modestly since 1994.

The reported catch of blue sharks grossly underestimates both the actual catch (sum of landed catch and discards) and the catch mortality. In recent years, almost all catch mortality can be attributed to hooking and post-release mortality in pelagic longlines. Bycatch appears persistently along the edge of the continental shelf and in basins on the Scotian Shelf. Mortality from derbies and recreational shark fishing accounts for less than 3% of overall fishing-related mortality in Canadian waters.

Blue sharks have negligible commercial value in Canada and large quantities (approximately 1400 mt annually) are discarded by commercial pelagic fisheries. Their persistence to this point is partly attributable to their productivity relative to other sharks species, the fact that few mature females are caught either in Canadian or American waters, and the relatively low overall Canadian contribution to overall population mortality. At present, fishing-related sources of mortality in Canadian waters appear to be sustainable, although large quantities of discards remain unutilized.

Situation actuelle de la population de requin bleu (*Prionace glauca*) de l'Atlantique Nord dans les eaux canadiennes de l'Atlantique et menaces pesant sur celle-ci

RÉSUMÉ

Les études de marquage traditionnel et par satellite indiquent que les requins bleus sont répartis sur une grande échelle et hautement migrateurs dans les eaux du Canada atlantique et de l'Atlantique Nord, sans preuve de résidence toute l'année dans les eaux canadiennes.

Il n'existe pas d'indice d'abondance indépendant de la pêche pour les requins bleus dans les eaux canadiennes. Les taux de prises normalisés provenant des observateurs sur les palangriers de pêche pélagique fournissent un indice de l'abondance locale à court terme, mais ne semblent pas refléter l'abondance de la population. L'abondance de la population dans l'Atlantique Nord semble avoir légèrement diminué depuis 1994.

Les prises déclarées de requins bleus sous-estiment nettement les prises réelles (somme des prises débarquées et des rejets) et la mortalité par capture. Au cours des dernières années, presque la totalité de la mortalité par capture peut être attribuée à l'hameçonnage et à la mortalité après rejet dans la pêche pélagique à la palangre. Les prises accessoires se font constamment le long du bord du plateau continental et dans les bassins du plateau néo-écossais. La mortalité due aux tournois de pêche et à la pêche récréative au requin représente moins de 3 % de la mortalité par pêche globale dans les eaux canadiennes.

Les requins bleus ont une valeur commerciale négligeable au Canada et de grandes quantités (environ 1 400 tm par année) sont rejetées par des pêches commerciales du poisson pélagique. Leur persistance à ce stade est en partie attribuable à leur productivité par rapport aux autres espèces de requins, au fait que peu de femelles matures sont capturées dans les eaux canadiennes ou américaines, et à la contribution générale assez faible du Canada à la mortalité de l'ensemble de la population. À l'heure actuelle, les sources de mortalité par pêche dans les eaux canadiennes semblent être durables, bien que de grandes quantités de rejets restent sous-exploitées.

INTRODUCTION

The blue shark (*Prionace glauca)* is a large temperate and tropical pelagic shark species of the family Carcharhinidae that occurs in the Atlantic, Pacific and Indian oceans. The species is highly migratory, with tagging results suggesting that there is a single well-mixed population in the North Atlantic (Casey and Kohler 1991). In Canadian waters the blue shark has been recorded off southeastern Newfoundland, the Grand Banks, the Gulf of St. Lawrence, the Scotian Shelf and in the Bay of Fundy. At certain times of the year, it is probably the most abundant large shark species in eastern Canadian waters (Templeman 1963).

The inherent vulnerability of sharks and other elasmobranchs to overfishing and stock collapse is well documented. FAO's *International Plan of Action for the Conservation and Management of Sharks* (FAO 1998) concluded that many of the world's shark species are severely depleted, while an American Fisheries Society policy statement noted that most elasmobranch populations decline more rapidly and recover less quickly than do other fish populations (Musick et al. 2000). Indeed, the low productivity of elasmobranchs compared with teleosts is well established, which is largely a result of their low fecundity and late age at sexual maturation. Although the blue shark is among the more productive of pelagic shark species (Cortés 2000), a sustainable catch level or fishing mortality has never been calculated for blue sharks in the North Atlantic. Blue sharks are the primary bycatch species in most large pelagic fisheries, yet are not considered a desirable species by most nations. As a result, most of the sharks that are caught are then discarded, with some associated mortality. Discard statistics by all nations are poor (ICCAT 2009). An additional complication is the highly migratory nature of blue sharks, which splits their residency between the high seas and national waters.

In 2006, Blue Shark (*Prionace glauca*) was designated as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), with the following justification (see: COSEWIC 2006):

> *This species is a relatively productive shark (maximum age 16-20 years, mature at 4-6 years, generation time 8 years, 25-50 pups every two years), but as an elasmobranch, populations are susceptible to increased mortality from all sources including from human activities. The species is considered to have a single highly migratory population in the North Atlantic, of which a portion is present in Canadian waters seasonally. The abundance index which is considered to best represent the whole population has declined 60% 1986-2000 but another index shows no longterm trend for the whole population 1971-2003. Indices of abundance in and near the Canadian waters show variable trends from no decline to 60% decline from the 1980s to early 2000s.There is evidence for a decline in mean length in longline fisheries in Canadian waters 1986-2003.The primary threat is bycatch in pelagic longline fisheries; although the threat is understood and is reversible, it is not being effectively reduced through management. Assessing the impact of bycatch on the population would benefit from better information on proportion of individuals discarded which survive. It appears that recent fishery removals from the North Atlantic have been several tens of thousands of tons annually. Estimated Canadian removals, a small proportion of the total, have been declining since the early 1990s and recently have averaged around 600 t per year.*

The present document provides a summary of current population status and threats to this species in both Canadian waters and across the North Atlantic population. COSEWIC will use this information to aid in its next population status report for blue shark, which is scheduled for 2016.

LIFE HISTORY CHARACTERISTICS

REPRODUCTION

The blue shark is a viviparous species, with litters usually consisting of 25 to 50 pups after a gestation period of between 9 and 12 months. It is possible that there is a resting year after birth, but this remains unconfirmed (Snelson et al. 2008). Birth is believed to take place in the southwest or central Atlantic in the late winter or spring (Tavares et al. 2012; Vandeperre et al. 2014a). Newborn pups measure 35 to 50 cm in total length (TL). After copulation the females may retain and nourish the spermatozoa in the oviducal gland for months or years while awaiting ovulation.

In the northwest Atlantic, male length at 50% maturity has been reported at 218 cm TL (Nakano and Stevens 2008), which is somewhat larger than that reported for the Mediterranean (Megalofonou et al. 2009) and north Pacific (Nakano and Stevens 2008). Female length at 50% maturity appears to be about 220 cm TL in both the Atlantic and Pacific (Pratt 1979; Nakano and Stevens 2008). Age at maturity is estimated to be 4-6 years for males and 5-7 years for females worldwide (Nakano and Stevens 2008), but would be about 7 years in the Northwest Atlantic based on the growth curve of Skomal and Natanson (2003).

Size at sexual maturity in Canadian waters was assessed in examinations of more than 2000 blue sharks landed at shark tournaments (Campana et al. 2004). Fork length (FL) at maturity varied between 193-210 cm for males, with a length at 50% maturity of 201 cm. Mature females were seldom caught at shark tournaments and length at maturity could not be estimated.

NATURAL MORTALITY

The instantaneous natural mortality rate (M) has never been directly estimated in blue sharks. Therefore, various studies have inferred M in blue sharks using meta-analysis of observed relationships between growth rate, mortality rate, and/or longevity. The inferred values for M range from 0.07 to 0.48 (Campana et al. 2004), with an overall mean of 0.23. Since M would be expected to vary inversely with growth rate, the importance of an accurate growth model is clear.

AGE AND GROWTH

There are no well validated age and growth models for blue sharks. Skomal and Natanson (2003) used vertebral sections to estimate age, concluding that longevity was between 16 and 20 years. Growth rate based on whole vertebrae gave comparable results to those based on vertebral sections, but only until Age 8 (MacNeil and Campana 2002). In neither study was there evidence of sexually dimorphic growth before sexual maturity, although Skomal and Natanson (2003) noted a slightly reduced growth rate for mature males. Blue sharks to an age of 12 years, based on whole vertebrae, have been observed in the Mediterranean (Megalofonou et al. 2009), while a maximum age of 22 years has been observed in the Indian Ocean; this latter age was validated as accurate with bomb radiocarbon (Campana, unpublished).

Generation time, which is the average age of parents in the current cohort, is estimated as the age at which 50% of the females are mature plus 1/M (where M=0.23; see above). Therefore, generation time is 11.3 years (or 7 + 1/0.23).

DISTRIBUTION, MIGRATION AND DESIGNATABLE UNITS

Blue sharks are known to be an abundant pelagic shark species in most of the world's temperate oceans. They are widely distributed in marine waters with a bottom depth greater

than about 50 m and have a strong association with temperatures of between 10 and 25 °C (Nakano and Stevens 2008; Campana et al. 2011a).

DISTRIBUTION IN CATCH

Commercial catch locations can provide an indication of a species' distribution, although it may not show the full extent. Figure 1 shows the commercial catch location of blue sharks observed by at-sea fishery observers operating in the DFO Maritimes Region between 1998 and 2014. In Atlantic Canada, blue sharks are widely distributed in offshore and off-shelf waters, with extension to the far northeast in association with the Gulf Stream. Distribution on many areas of the continental shelf however is not demonstrated in Figure 1, since most of the captures are associated with the offshore swordfish fishery operating in the region. Figure 2 shows the commercial catch location of blue sharks in the offshore of Newfoundland and Labrador, as recorded by at-sea fishery observers operating in the DFO Newfoundland and Labrador Region between 1980 and 2012. Gillnet, longline and trawl fisheries which target Atlantic cod (*Gadus morhua*), white hake (*Urophycis tenuis*), and monkfish(*Lophius americanus*) capture blue shark on the Grand Banks in NAFO Divisions 3LNO, and St. Pierre in NAFO Subdivision 3Ps. Catches in other fisheries, such as those that targeted swordfish, bigeye tuna and porbeagle, are found in areas off the shelf.

Blue sharks are rarely reported in the Gulf of St Lawrence and the western coast of Newfoundland by at-sea fishery observers operating in these areas.

DISTRIBUTION AND MIGRATION FROM TAGGING STUDIES

The migration pattern of blue sharks in Canadian waters was analyzed on the basis of tag recaptures from four sets of tagging studies. A total of 2017 tags were applied to blue sharks in a Canadian tagging program carried out between 1961 and 1980 (Burnett et al. 1987). Most of the tags were applied before 1972, which makes this study most applicable to the early years of the longline fishery. With only 17 recaptures from this study, it was difficult to draw many conclusions. However, it was clear that at least some of the sharks migrated freely between inshore and offshore waters, and between Canadian and U.S. waters (Campana et al. 2004).

A second tagging study was carried out by the National Marine Fisheries Service of the U.S. in cooperation with Canadian fishers. This study applied 916 tags to blue sharks in Canadian waters between 1971 and 2002, with most of the tagging effort taking place after 1990. Most of the 188 recaptures in Canadian waters were tagged in the U.S.; a pattern which would be expected given that most of the tagging effort was concentrated in the U.S. (Figure 3; bottom panel). In contrast, most of the tags applied in Canadian waters were later recaptured in the central and eastern Atlantic, as far away as Africa (Figure 3; top panel).

A third ongoing tagging study, conducted by DFO's Shark Research Laboratory, in cooperation with recreational shark fishermen at annual shark derbies, has tagged 2374 blue sharks since 2006. Of the 54 recaptures to date, most have been recaptured in the central Atlantic (Figure 4).

A fourth tagging study was carried out using pop-up satellite archival tags (PSAT), which give a fishery-independent view of blue shark migration, since they do not require capture (Campana et al. 2011a). Of the 23 successful pop-ups, all blue sharks moved into warmer off-shelf waters to the east and south in the winter, often in association with the Gulf Stream (Figure 5).

Quite a few of the tag recaptures were made after periods at liberty of more than one year, but there did not appear to be any obvious tendency for recaptures to be made near the tagging location. Thus, there was no evidence of repeated annual returns to a particular location, as is often observed in tagged groundfish.

Although the four tagging studies extend over a period of more than 50 years, there is no indication of any change in blue shark distribution over that period.

DESIGNATABLE UNITS

Both the commercial catch locations and the four tagging studies indicate that blue sharks are highly migratory, spend considerable amounts of time outside of Canadian waters on the high seas, and show no obvious signs of population differentiation in the Northwest Atlantic. This is consistent with published views that there is a single population of blue sharks in the North Atlantic (Vandeperre et al. 2014b).

POPULATION TRENDS

There are no fishery-independent indices of abundance for the North Atlantic blue shark population. The only index of abundance for the population as a whole is that based on the average of numerous catch-per-unit-effort (CPUE) indices from national pelagic longline fleets, where blue sharks appear to be of intermediate vulnerability compared to other shark species in the North Atlantic (Cortes et al. 2010). The averaged ICCAT index for the North Atlantic shows no marked trend in relative abundance between 1958 and 1994, with a decline thereafter (ICCAT 2012). The net decline since 1958 was approximately 20-30%. A population model based on the CPUE indices indicated that biomass in 2010 remained above biomass at maximum sustainable yield (B_{msy}) and that no overfishing was occurring, although the ICCAT report further acknowledged that the population model was highly uncertain.

Several regional indices of blue shark abundance are broadly consistent with the ICCAT assessment. Baum (2002) reported that CPUE derived from U.S. logbooks increased in the area surrounding the Grand Banks, the area of highest blue shark numbers, between 1986 and 1993, declining thereafter. The net decline in that region was 9.6% between 1986 and 2000. The net decline was 60% in the Northwest Atlantic as a whole between 1986 and 2000 (Baum et al. 2003; but see rebuttal by Burgess et al. 2005). A comparable analysis of U.S. pelagic longline CPUE, this time based on observer data, suggested that CPUE first increased and then decreased between 1992 and 2005, for a net decline of 53% (Baum and Blanchard 2010).

In other regions of the Atlantic, Mejuto et al. (2008) reported that the CPUE of the Spanish longline fleet in the North Atlantic increased between 1997 and 2000, and then declined by 13% to 2007. Similarly, Tavares et al. (2012) reported a significant decline in standardized CPUE off northeastern South America between 1998 and 2007.

CATCH RATE OF BLUE SHARK IN CANADIAN WATERS

The catch rate of blue sharks in the recreational shark fishery is not a useful indicator of abundance largely because few records of small (and released) sharks are maintained (Campana et al. 2004). Therefore, catch rates in the shark derbies and non-derby recreational fishery were not estimated for this assessment.

Calculations of commercial catch rate (ln-transformed kg/hook) were based on directed pelagic longline catches for swordfish in the months June to October from 1995 onwards, which account for most of the blue sharks caught in Atlantic Canada. All data came from the Maritimes Region At-Sea Observer Program and are thus considered more accurate than logbook data, at least after 1997. Between 1995 and 1997, certain Observers failed to report any blue sharks; therefore trips in those years where no blue sharks were reported were removed from the analysis. In addition, only vessels which fished at least 10 sets in at least 2 years were included. An initial full model, based on 1864 sets, identified many significant spatial and temporal factors

and their interactions, but there were too many null cells in the factor array to be useful (Table 1). A series of model simplications ended with a final generalized linear model (GLM) which included CFV (vessel identity) and year as significant factors (Table 2). Although the interaction term was also significant, the full model did not provide predictions for the year term and could not be used. Thus, only the main effects model was used for prediction.

The GLM of blue shark catch rate resulted in an estimated catch rate trend which largely paralleled that based on mean observed catch rates (Figure 6). There was no significant trend in CPUE between about 2001 and 2013. The year-to-year variability in the estimated trend was too large to be attributable to real changes in population abundance, and was more likely to reflect year-to-year differences in availability related to oceanographic conditions, the relatively low observer coverage, or both. As such, it is unlikely that Canadian blue shark catch rates by themselves can be used to monitor population abundance.

BLUE SHARK HABITAT

Blue sharks are pelagic sharks seldom found over ocean bottom less than 50 m deep. PSAT tags applied to 23 blue sharks between 2003 and 2007 demonstrated that blue sharks remain in near-surface waters (less than 50 m) for most of the summer and fall, moving into deeper waters near the end of November (Figure 7). Mean depth while on the continental shelf was 29 m. The temperature occupied ranged between 10-20 °C, with a mean of 15 °C (Figure 7).

The summer/fall residency in surface waters, invariably associated with swordfish and tuna, makes this period one of high availability to large pelagic longline gear. On the other hand, the movement to deeper offshore water in late fall tends to reduce the interaction of blue shark with pelagic longline fisheries.

There are no known important habitats for blue sharks in Canadian waters. Mating, birth and nursery areas are all believed to be in international waters to the south and east (Tavares et al. 2012; Vandeperre et al. 2014a).

THREATS

All known threats to the North Atlantic blue shark population are due to fishing, either within Canadian waters or elsewhere within the population range across the North Atlantic. With the exception of the recreational shark fishery, all blue sharks are caught as bycatch of other fisheries; primarily the pelagic longline fishery for swordfish and tuna. A substantial source of mortality is hooking and post-release mortality. These sources are addressed below.

COMMERCIAL LANDINGS

Blue shark landings and/or nominal catch in the Canadian Atlantic (NAFO Areas 2-5) are known only for Canadian vessels landing their catch or for foreign vessels operating under 100% observer coverage within the exclusive economic zone (EEZ). Landings have averaged about 10 metric tonnes (mt) per year since 2004 (Table 3). Only Canadian, Japanese and Faroese vessels are known to have caught significant quantities of blue shark in Canadian waters. In the Northwest Atlantic as a whole (north of Florida), mean reported catches are much larger, averaging about 20,000 mt annually until 2010 (the last complete year of statistics). North Atlantic nominal catches are substantially larger, averaging over 37,000 mt since 2008. The marked increase in reported North Atlantic catches since 2007 is due to increased reporting of dead discards rather than any substantial increase in landings.

DFO Newfoundland and Labrador Region Zonal Interchange File Format (ZIFF) data contain very limited landings of blue shark (Figure 8). The landings in 1994 were due to unspecified longline fisheries. The landings in 1995 and 1996 were due to swordfish-directed longline fisheries. Landings in 2002 represent Atlantic cod and redfish (*Sebastes sp.*) fisheries. The increased landings in 2005 represent a bigeye tuna-directed longline fishery.

OBSERVER BYCATCH

The Maritimes Region At-Sea Observer Program has maintained 100% coverage of foreign fisheries in the Canadian zone since 1987, thus allowing accurate determinations of both nominal catch and bycatch. The Maritimes Region At-Sea Observer Program coverage of domestic pelagic longline vessels has been considerably less (approximately 5% since 2004). Nevertheless, Maritimes Region At-Sea Observer Program observations indicate that Canadian, Japanese and, in earlier years, Faroese longliners caught substantially larger numbers of blue sharks than would otherwise be known from nominal catch statistics (Table 4). Blue shark bycatch in fisheries other than that for large pelagics was much smaller, although the 1-2 mt observed on NAFO 4X groundfish longlines could add up to 20-60 mt annually when pro-rated across non-observed fishing trips.

Observed catch and bycatch between 1990 and 1999 averaged about 250 mt annually, with most of that coming from Japanese vessels (Table 4). Since 1999, virtually all observed catch and bycatch has been caught and discarded by Canadian vessels.

The Newfoundland and Labrador Region At-Sea Observer Program coverage in some fisheries has been less than 5%. However, as the only source of discard data in Newfoundland waters, it provides important information. Between 1980 and 2012, blue shark has been captured in gillnet, longline and trawl fisheries which target Atlantic cod, white hake, monkfish, as well as swordfish, bigeye tuna and porbeagle (Figure 9). In addition, blue shark are also captured in some trawl fisheries which target Atlantic cod and yellowtail flounder (*Limanda ferruginea*).

ESTIMATION OF UNOBSERVED BLUE SHARK BYCATCH

To determine the magnitude of the blue shark bycatch in the various large pelagic fisheries, bycatch was estimated by country, fishery, quarter and year from the Maritimes Region At-Sea Observer Program observations made between 1986-2014, with bycatch defined as the summed weight of the kept and discarded blue sharks relative to the summed large pelagic catch (tuna, swordfish and porbeagle). The summed large pelagic catch accounted for virtually all of the catch, and its use in the estimation avoided problems associated with the species sought being unknown. The analysis was restricted to Canadian, Japanese and Faroese vessels, since they accounted for more than 99% of the blue shark catch. Bycatch in the foreign fisheries was fully observed, so estimation was used more to calculate bycatch proportion than bycatch weight for foreign vessels. Total pelagic catch for each cell was determined from ZIFF for Canadian vessels and from the Maritimes Region At-Sea Observer Program for foreign vessels. Full details on the estimation protocol are presented in Campana et al. (2011b).

Blue sharks dominated the bycatch of large pelagic longlines, accounting for 46% of total observed catch weight since the year 2000. Blue shark bycatch in the porbeagle fishery was substantially less, averaging 7%. Since there were no consistent trends across years, the weighted mean proportion (weighted by number of observed sets) across years was used to estimate the Canadian bycatch. Therefore, each quarter and fishery was characterized by a unique bycatch proportion, but this proportion was maintained for all years. This method of calculation is considered to be less susceptible to sampling variability than was the year by year

method of Campana et al. (2002). In addition, the sum of the large pelagic catches was updated and revised from those of Campana et al. (2004).

Blue shark bycatch and proportions for each year and quarter in the Canadian tuna and swordfish fisheries are presented in Table 5. Bycatch ratios of blue shark to target species often exceeded 100%. Annual bycatch estimates have averaged about 1400 mt annually since 2000, with an increasing trend largely due to increased catches of tunas and swordfish.

Blue shark bycatch in the pelagic longline fishery catches both immature and mature sharks, ranging from newborns to those over 3 m in length (Figure 10). The swordfish and tuna fisheries tend to catch slightly larger blue sharks than does the porbeagle fishery.

Blue shark bycatch also occurs in the groundfish fisheries, but is very small compared to that in the swordfish and tuna fisheries (Table 6; Figure 11).

Total blue shark bycatch in various fisheries in Newfoundland and Labrador was estimated based on observed bycatch and landings (Figure 12). In 1993, the total estimated bycatch peaked at 60 mt based on swordfish and tuna-directed fisheries. In recent years, bycatch of blue sharks has not exceeded 22 mt, and has averaged only 12 mt over the period 2002-2012. Most bycatch in recent years has occurred in groundfish-directed fisheries.

HOOKING AND POST-RELEASE MORTALITY

Prior to 1994, most shark bycatch was killed by finning. After finning was banned in 1994, virtually all blue sharks caught with pelagic longlines in Canadian waters were discarded or released after capture. Many of these sharks are alive at the time of retrieval to the boat and continue to remain alive after release. However, a significant percentage of sharks die while on the hook (hooking or capture mortality), while a significant percentage of the live releases subsequently die due to stress or injury (post-release mortality). Hooking mortality can be measured by onboard observers, and has been assessed more carefully since 2010 as a result of additional training. However, post-release mortality requires continual monitoring through use PSAT tags (Campana et al. 2009).

Close to 20,000 blue sharks have been observed on large pelagic fishing vessels between 2010 and 2014 (Table 7). Of those where condition could be assessed at release, and assuming that moribund and shark-bit sharks were dead, the annual percentage of dead blue sharks ranged between 11-37%, with an overall mean of 15%. This value is slightly higher than the 12% observed value for the years 2001-2008 and slightly lower than the 20% value measured by biologists in a previous study (Campana et al. 2009).

Post-release mortality of blue sharks was measured in a previous study (Campana et al. 2009) and found to differ with the condition of the shark at release. Healthy, jaw-hooked sharks showed no mortality (n=10), while injured sharks (n=27) experienced a 33% mortality. Table 7 indicates that an annual percentage of 10-38% of the assessed blue sharks were reported by observers as being injured at the time of release, with an overall mean of 25%. Applying the 33% mortality rate to the 25% injury rate yields an estimated overall post-release mortality of live blue sharks of 8.25%. When combined with a 15% hooking mortality, overall non-landed fishing mortality of blue sharks captured in the pelagic longline fishery is estimated at 23%. According to the Observers who made the observations, this estimate of fishing mortality is likely a minimum estimate, since they noted that they often got only a quick glimpse of each blue shark as it was brought up to the rail and cut off, leaving only those that were badly injured or clearly dead being recorded as such.

Hooking and post-release mortality in the recreational shark catch-and-release fishery has not been measured, but is believed to be very low. A 10% mortality rate was assumed here.

BYCATCH DISTRIBUTION

The large pelagic fisheries in the northwest Atlantic all catch a broad range of desired catch and undesired bycatch, but blue shark bycatch in the pelagic longline swordfish fishery is by far the largest. To identify blue shark bycatch distribution and abundance in the Canadian swordfish fishery, observer data from swordfish or tuna trips on the Canadian longline fleet were analyzed to estimate blue shark catch proportions in relation to the sum of target catch plus bycatch weight. Target species were defined as swordfish, bigeye, yellowfin and albacore tuna. The 20 most important bycatch species included the sharks, bluefin tuna, marlins, turtles and several other minor species. All catches were filtered to remove sets where total catch was less than 200 kg (approximately 9% of sets). Observations were then grouped into 5 year periods, with spatial aggregation at 30 minute blocks.

Large pelagic catches tended to be largest along the edge of the Scotian and Newfoundland shelves, offshore of the shelves in the Gulf Stream, and within Emerald and Lahave basins (Figure 13). Blue shark bycatch proportions tended to be largest where total catch was largest, except near the entrance to the Laurentian Channel. Seasonally, blue shark bycatch tended to be largest in the October to December time period (Figure 14).

RECREATIONAL SHARK FISHERY AND SHARK TOURNAMENTS (DERBIES)

Federal regulations state that the recreational shark fishery is to be catch and release only, with the exception of shark derbies. Prior to 2006, no sharks less than 180 cm (6 feet) in length could be landed. Beginning in the summer of 2006, rules for all derbies were changed such that all blue sharks less than 240 cm (8 feet) were to be released alive, preferably after tagging. Tagging was voluntary, but was strongly encouraged by DFO Science. Total derby landings have been capped at 20 mt.

All shark derbies in Atlantic Canada are currently located in Nova Scotia. On average, there have been 5-6 derbies held each year between late July and mid-September. Fishing locations are primarily located on the continental shelf and on Georges Bank (Figure 15).

The weight of sharks landed at recreational shark tournaments has increased from around 4 mt in 1993, the first year of the derbies, to an average of 11 mt since 2006 (Table 8). These figures are undoubtedly underestimates of actual fishing mortality, since anecdotal evidence indicates that some fishermen retain and kill blue sharks throughout the derby fishing period until or unless a larger shark is caught. Although shortfin mako (*Isurus oxyrinchus*), thresher (*Alopias vulpinus*), and porbeagle (*Lamna nasus*) have all been caught at derbies, blue sharks account for 99% of all landings.

The size and sex composition of blue sharks landed at the derbies has changed markedly since the minimum size regulations were changed at the beginning of 2006. Prior to 2006, the length composition was dominated by immature sharks of both sexes with an overall sex ratio of almost exactly 50% (Figure 16). After 2006, 85% of the sharks landed were males, most of them mature.

Blue shark recreational catch outside of derbies is infrequently recorded in recreational fishing logs. Previous estimates suggested that non-derby catches (and releases) were approximately 12.5 mt per year (Campana et al. 2004).

EXPLOITATION RATE FROM TAG-RECAPTURES

The exploitation rate of blue sharks in Canadian waters was estimated through Petersen analysis of tag recaptures. Estimates of commercial exploitation rate were not possible given the very low reporting rate of a discarded species by commercial fishermen. To provide an estimate of exploitation rate which is unaffected by reporting rate, we restricted the analysis to

the recreational fishery, which is highly motivated to report any recovered tags since they do almost all of the tagging. Estimates of exploitation rate (E) were calculated as:

$$E = R/(T*(1.0-M_t)*\exp(-(L))*\exp(-(M_n*P)))*RR, \text{ where}$$

R = Number of tags recovered
T = Number of tags
M_t = Tag mortality
L = Tag loss
M_n = Natural mortality
P = Period relative to 1 year
RR = Tag reporting rate

Estimates of natural mortality (M_n = 0.22) and tag loss (L = 0.11) were adopted from the NMFS tagging program on blue sharks (Silva 2008). We assume no tagging mortality (M_t = 0.0) associated with the scientific and recreational tagging in this study and 100% reporting rate (RR = 1.0) by recreational fishermen, both within and outside of derbies. Annual exploitation rates were calculated using only those recoveries occurring within 365 days of tagging (P=1.0). Annual exploitation rates were transformed to instantaneous fishing mortality rates (F) as:

$$F = \ln(1.0-E)$$

A total of 2374 Floy tags were applied to blue sharks by recreational fishermen between 2006 and 2014, of which 13 were recaptured by recreational fishermen within Canada (Table 9). An additional 41 tags were recaptured by commercial fishermen or outside of Canadian waters, largely by Spanish longliners fishing in the central Atlantic. Calculated exploitation rates by recreational fishermen within Canada ranged between 0 and 2.3% annually, with an overall mean of 0.3% (Table 10). Exploitation rate by foreign longliners was considerably higher, especially in the first few years of the tagging program. These results suggest that recreational fishing mortality within Canadian waters is very low to the point of being undetectable – about 1% that of the natural mortality rate. Similar calculations applied to 916 tags applied by Canadian recreational fishermen to blue sharks in Canadian waters as part of the NMFS tagging program produced a comparable mean exploitation rate of 0.78% between 1992 and 2002 (Campana et al. 2004).

Tag recaptures by shark derby participants (R=3) compared to non-derby recreational fishermen and charters (R=4) were of comparable magnitude, consistent with previous calculations suggesting that derby and non-derby recreational exploitation rates are similar (Campana et al. 2004).

It is important to note that the 0.3% estimate of exploitation rate mentioned above reflects only the Canadian recreational exploitation rate and not that on the population as a whole.

TOTAL CATCH MORTALITY

Total estimated annual blue shark catches, discards and catch mortality in Canadian waters are shown in Table 11. Discards from the Canadian large pelagic fisheries constituted the largest proportion of blue sharks caught in Canadian waters since 1986. However, total estimated catch mortalities, based on the discard mortalities presented earlier, are lower, averaging around 400 mt per year in recent years (Table 11; Figure 17). The proportion of catch mortality contributed by derby and recreational shark fishing was small, averaging less than 3% of the total catch mortality in recent years.

SUSTAINABLE MORTALITY LEVEL FOR BLUE SHARKS IN CANADIAN WATERS

Blue sharks in Canadian waters are part of a North Atlantic-wide population, and thus are subject to assessment and regulation by ICCAT. Although ICCAT has completed a stock assessment for blue sharks, which ICCAT itself acknowledges as uncertain, no reference points have been set and there are no catch or mortality regulations (ICCAT 2009, 2012). National allocations have been set for many of the tuna and swordfish species, but such do not exist for any of the sharks other than porbeagle. At present therefore, there are no limits or estimates of sustainable mortality in place for blue sharks in Canadian waters.

There are several possible approaches to calculating national allocations of a transboundary fish stock, one of which is the use of national catch (landings plus discards) histories. However, the use of catch histories has no scientific basis for determining biological reference points, and appears particularly unsuitable for a non-retained bycatch species for which few countries have reported estimates of discard mortality. As an example of the arbitrarity of catch histories for blue shark, Canada's reported blue shark catch and discard mortality would be 0% of the North Atlantic reported blue shark longline catch if based on the most recent five years, 0.35% if based on the last 7 years, and 1.3% if based on the most recent 10 years (ICCAT 2014). A calculation based on the 10 years leading up to the last ICCAT stock assessment in 2008 would yield 3.1%. Catch histories based on landings, as opposed to discard mortalities for which only Canada has reported statistics, would be very close to 0% for Canada. Clearly, catch histories based on reported blue shark catches would not provide any meaningful information for determining if Canadian blue shark discard mortalities are biologically sustainable.

Another possible, more scientifically defensible approach to calculating sustainable mortality levels within Canada is to determine the sustainable mortality of the entire North Atlantic blue shark population, and then pro-rate it based on Canada's share of the catch of targeted ICCAT fisheries which also catch blue sharks. The catch statistics for valued (targeted) ICCAT species are considered to be much more accurate than those of discarded species, thus making them far more useful in calculations.

The most recent stock assessment for the North Atlantic blue shark stock was conducted in 2008, using data up to the end of 2007. This assessment provided explicit estimates of Maximum Sustainable Yield (MSY) yield only from the Bayesian surplus production model (ICCAT 2009, 2012). The base case MSY yield from that model was 9,334 mt, with a range of 5,664 to 24,659 mt. Given that recent blue shark catches have averaged around 60,000 mt, it is clear that these MSY estimates, based on the Bayesian model, provide a pessimistic view of stock status. Unfortunately, projections of MSY yield were not made from the alternative, more optimistic model tabled in the assessment. Therefore, the Bayesian model MSY estimates were not used, but rather estimated from model-estimated ratios as follows below.

Virgin biomass (B_0) of North Atlantic blue sharks was estimated to fall in the range of 861,081-1,923,000 mt (ICCAT 2009). B_{2007}/B_0 was reported as being in the range of 0.67-0.93, while B_{2007}/B_{msy} was reported as 1.87-2.74 (ICCAT 2012). F_{msy} was reported as 0.15, which corresponds to an exploitation rate of 14%. Rearranging the above equations to calculate B_{msy}, and multiplying the exploitation rate at MSY by B_{msy}, blue shark catch at MSY was estimated for all combinations of upper and lower values, producing eight estimates of MSY which span the highest possible and lowest possible values. These estimates lay in the range of 29,330 to 133,200 mt, with an overall mean of 69,800 mt. While the legitimacy of this analytical derivation was confirmed by the ICCAT scientist who ran all of the blue shark assessment models (E. Cortés, National Marine Fisheries Service, Panama City, FL, USA, pers. comm.), he also noted that it was not appropriate to include the output of the [more optimistic] age-structured models in any calculations, since there is no simple way to extract MSY from the model that was used.

Implicit in this statement is that MSY yield without the inclusion of the age-structured models would result in the low 9,334 mt value reported earlier.

More than 96% of the reported blue shark catches in the North Atlantic are caught by pelagic longlines, indicating that overall blue shark MSY yield can be largely attributed to this fishing gear. Of the pelagic longline species managed by ICCAT, Canada fishes several target species whose pelagic longline fisheries also catch blue sharks: swordfish, albacore, bigeye, yellowfin and bluefin tuna. In 2007, the year of the last full blue shark assessment, the Canadian catch (including dead discards) of swordfish was 1,387 mt of the total North Atlantic longline catch (plus discards) of 11,748 mt. Equivalent values for longline-caught North Atlantic albacore (27 mt of 3237 mt), Atlantic bigeye (144 mt of 46,232 mt), and western Atlantic yellowfin (276mt of 13,557 mt) were based on smaller Canadian catches, as was the 55 mt of Canadian bluefin allocated to longline bycatch (out of a total western bluefin longline catch of approximately 600 mt). Despite the fact that Canada's allocation of the tuna species is relatively small, blue sharks are caught throughout the North Atlantic and thus the blue shark MSY catch must be apportioned across all countries fishing pelagic longlines in the North Atlantic. For example, even if Canada was allocated and caught 100% of the North Atlantic swordfish quota, it wouldn't mean that they were entitled to 100% of the blue shark MSY, since blue sharks are caught in large numbers by other countries fishing tunas. In 2007, Canada's swordfish/tuna catch was 2.5% of the total North Atlantic swordfish/tuna longline catch. Applying this percentage to the range of blue shark MSY values would result in a Canadian portion of blue sharks of between 733-3330 mt, with an overall mean of 1550 mt. This approach assumes that the proportion of blue sharks relative to each of the five targeted ICCAT species are similar, and that the proportion is spatially invariant throughout the North Atlantic. These assumptions are unlikely to be correct, but the same assumptions are made by ICCAT in estimating blue shark catch throughout the Atlantic Ocean (ICCAT 2009). Based on this approach, blue shark mortality associated with fishing (i.e. landings, dead discards and post-release mortalities) of less than about 1550 mt annually should be sustainable in Canadian waters. Thus, the recent annual catch mortalities of about 400 mt would be considered sustainable under this approach, although the analytical uncertainties around the estimated range of sustainable levels of 733-3330 mt indicate that catch mortalities may be close to the lower range of the sustainable level.

DISCUSSION

Several conclusions concerning blue shark distribution, status and threats can be reached based on the analyses reported in this study.

Both conventional and satellite tagging studies indicate that blue sharks are widely distributed and highly migratory across both Atlantic Canada and the North Atlantic waters, with no evidence of year-round residency in Canadian waters.

There is no fishery-independent index of abundance for blue sharks in Canadian waters. Standardized catch rates from observers on pelagic longline vessels provide an index of local, short-term abundance, but do not appear to reflect population abundance. Population abundance in the North Atlantic appears to have decreased modestly since 1994.

The reported catch of blue sharks grossly underestimates both the actual catch (i.e. sum of landed catch and discards) and the catch mortality. In recent years, almost all catch mortality can be attributed to hooking and post-release mortality in pelagic longlines. Mortality from derbies and recreational shark fishing accounts for less than 3% of overall fishing-related mortality in Canadian waters. Canadian sources of blue shark mortality remain a small percentage of total (international) mortality to the North Atlantic population.

Blue sharks have negligible commercial value in Canada and are discarded in large quantities, about 1400 mt annually, by Canadian commercial pelagic fisheries. The species persistence to this point is partly attributable to its productivity relative to other shark species, the fact that few mature females are caught either in Canadian or American waters, and the relatively low overall Canadian contribution to overall population mortality. At present, fishing-related sources of mortality in Canadian waters appear to be sustainable, although large quantities of discards remain unutilized.

ACKNOWLEDGEMENTS

The authors thank Art Gaeten of Blue Shark Fishing Charters for providing access to his detailed catch records. Ross Jones, Mike James and Michael Eagles provided helpful comments on the manuscript.

REFERENCES

Baum, J. K. 2002. Determining the effects of exploitation on shark populations using fishery-dependent data. M.Sc. Thesis. Dalhousie University, Halifax, NS. 121 p.

Baum, J. K. and Blanchard, W. 2010. Inferring shark population trends from generalized linear mixed models of pelagic longline catch and effort data. Fish. Res. 102:229-239.

Baum, J. K., Myers, R. A., Kehler, D. G., Worm, B., Harley, S. J., and Doherty, P. A. 2003. Collapse and conservation of shark populations in the northwest Atlantic. Science 299:389-392.

Burgess, G. H., Beerkircher, L. R., Cailliet, G. M., Carlson, J. K., Cortés, E., Goldman, K. J., Grubbs, R. D., Musick, J. A., Musyl, M. K., and Simpfendorfer, C. A. 2005. Is the collapse of shark populations in the Northwest Atlantic Ocean and Gulf of Mexico real? Fisheries 30:19-26.

Burnett, C. D., Beckett, J. S., Dickson, C. A., Hurley, P. C. F., and Iles, T. D. 1987. A summary of releases and recaptures in the Canadian large pelagic fish tagging program 1961-1986. Can. Data Rep. Fish. Aquat. Sci. 673:iii + 99 p.

Campana, S., Gonzalez, P., Joyce, W., and Marks, L. 2002. Catch, bycatch and landings of blue shark (*Prionace glauca*) in the Canadian Atlantic. DFO Can. Sci. Adv. Sec. Res. Doc. 2002/101. 40 p.

Campana, S., Marks, L., Joyce, W., and Kohler, N. 2004. Influence of recreational and commercial fishing on the blue shark (*Prionace glauca*) population in Atlantic Canadian Waters. DFO Can. Sci. Adv. Sec. Res. Doc. 2004/069. 67 p.

Campana, S. E., Joyce, W., and Manning, M. J. 2009. Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. Mar. Ecol. Prog. Ser. 387:241-253.

Campana, S. E., Dorey, A., Fowler, M., Joyce, W., Wang, Z., and Wright, D. 2011a. Migration pathways, behavioural thermoregulation and overwintering grounds of blue sharks in the Northwest Atlantic. PLoS ONE 6(2): e16854. doi:10.1371/journal.pone.0016854

Campana, S. E., Brading, J., and Joyce, W. 2011b. Estimation of pelagic shark bycatch and associated mortality in Canadian Atlantic fisheries. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/067: vi + 19p.

Casey, J. G. and Kohler, N. E. 1991. Long distance movements of Atlantic sharks from the NFS cooperative shark tagging program. Underwater Naturalist 19:87-91.

Cortés, E. 2000. Life history patterns and correlations in sharks. Reviews Fish. Sci. 8:299-344.

Cortés, E., Arocha, F., Beerkircher, L., Carvalho, F., Domingo, A., Heupel, M., Holtzhausen, H., Santos, M. N., Ribera, M., and Simpfendorfer, C. 2010. Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Aquat. Living Resour. 23:25-34.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2006. COSEWIC assessment and status report on the blue shark *Prionace glauca* (Atlantic and Pacific Populations) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa"vii + 46 pp.

FAO (Food and Agriculture Organization of the United Nations). 1998. International Plan of Action for the Conservation and Management of Sharks. FAO Document FI:CSS/98/3, Rome, Italy.

ICCAT (International Commission for the Conservation of Atlantic Tunas). 2009. Report of the standing committee on research and statistics (SCRS). ICCAT SCRS Report 2009. 270 p.

ICCAT. 2012. Report of the standing committee on research and statistics (SCRS). ICCAT SCRS Report 2012. 300 p.

ICCAT. 2014. Report of the standing committee on research and statistics (SCRS). ICCAT SCRS Report 2014. 344 p.

MacNeil, M. A. and Campana, S. E. 2002. Comparison of whole and sectioned vertebrae for determining the age of young blue shark (*Prionace glauca*). J. Northw. Atl. Fish. Sci. 30:77-82.

Megalofonou, P., Damalas, D., and de Metrio, G. 2009. Biological characteristics of blue shark, *Prionace glauca*, in the Mediterranean Sea. J. Mar. Biol. Assoc. U.K. 89:1233-1242.

Mejuto, J., Garcia-Cortés, B., Ramos-Cartelle, A., and de la Serna, J. M. 2008. Standardized catch rates for the blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*) caught by the Spanish longline fleet in the Atlantic Ocean during the period 1990-2007. ICCAT SCRS Doc. 2008/129.

Musick, J. A., Burgess, G., Cailliet, G., Camhi, M., and Fordham, S. 2000. Management of sharks and their relatives (Elasmobranchii). Fisheries 25(3):9-13.

Nakano, H. and Stevens, J. D. 2008. The biology and ecology of the blue shark, *Prionace glauca;* pp. 140-151. *In* Sharks of the Open Ocean: Biology, Fisheries and Conservation. Edited by M. D. Camhi, E. K. Pikitch, and E. A. Babcock. Blackwell Publishing. Oxford, U.K.

Pratt Jr., H. L. 1979. Reproduction in the blue shark, *Prionace glauca*. Fish. Bull. 77:445-470.

Silva, A. A. 2008. Population Dynamics of the Blue Shark, *Prionace glauca*, in the North Atlantic Ocean. Ph.D. Thesis, University of Washington, Washington, DC

Skomal, G. B. and Natanson, L. J. 2003. Age and growth of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. Fish. Bull. 101:627-639.

Snelson Jr., F. F., Burgess, G. H., and Roman, B. L. 2008. The reproductive biology of pelagic elasmobranchs; pp. 24-53. *In* Sharks of the Open Ocean: Biology, Fisheries and Conservation. Edited by M. D. Camhi, E. K. Pikitch, and E. A. Babcock. Blackwell Publishing, Oxford, U.K.

Tavares, R., Ortiz, M., and Arocha, F. 2012. Population structure, distribution and relative abundance of the blue shark (*Prionace glauca*) in the Caribbean Sea and adjacent waters of the North Atlantic. Fish. Res. 129-130:137-152.

Templeman, W. 1963. Distribution of sharks in the Canadian Atlantic (with special reference to Newfoundland waters). Bull. Fish. Res. Board Can. 140. 77 p.

Vandeperre, F., Aires-da-Silva, A., Santos, M., Ferreira, R., Bolten, A. B., Santos, R. S., and Afonso, P. 2014a. Demography and ecology of blue shark (*Prionace glauca*) in the central North Atlantic. Fish. Res. 153:89-102.

Vandeperre, F., Aires-da-Silva, A., Fontos, J., Santos, M., Santos, R. S., and Afonso, P. 2014b. Movements of blue sharks (*Prionace glauca*) across their life history. PLoS ONE 9(8): e103538. doi:10.1371/journal.pone.0103538.

TABLES

Table 1. Standardized catch rate model of blue sharks observed on pelagic longlines in Canadian waters of the Northwest Atlantic. Terms sequenced by Akaike information criterion (AIC) on main effects. Factor levels beyond YR (year) and VESSEL are SPECS (specifications): 1 = Bluefin Tuna Fishery, 2 = Swordfish/Bigeye Tuna Fishery, SEASON 1 = Spring-Summer, 2 = Fall-Winter, REGION 1 = NAFO Division 3, 2 = NAFO Division 4.

Parameter	Df	Deviance	Resid.Df	Resid.Dev	F	Pr(>F)
NULL	1864	9816	-	-	-	-
VESSEL	40	1041	1824	8775	7.44	0.000
SPECS	1	374	1823	8401	106.82	0.000
YR	18	368	1805	8033	5.84	0.000
SEASON	1	63	1804	7970	17.96	0.000
REGION	1	23	1803	7948	6.46	0.011
VESSEL:SPECS	16	321	1787	7626	5.74	0.000
VESSEL:YR	94	1022	1693	6604	3.11	0.000
VESSEL:SEASON	14	81	1679	6524	1.65	0.061
VESSEL:REGION	14	236	1665	6288	4.81	0.000
SPECS:YR	12	357	1653	5931	8.49	0.000
SPECS:SEASON	1	1	1652	5930	0.42	0.518
SPECS:REGION	1	3	1651	5926	0.97	0.326
YR:SEASON	16	161	1635	5766	2.87	0.000
YR:REGION	9	75	1626	5691	2.38	0.011
SEASON:REGION	1	3	1625	5688	0.98	0.324
Dispersion	3.5	-	-	-	-	-
Explained	42.1%	-	-	-	-	-

Table 2. Standardized catch rate model of blue sharks observed on pelagic longlines in the June-October Swordfish fishery.

Parameter	Df	Deviance	Resid.Df	Resid.Dev	F	Pr(>F)
NULL	779	2431	-	-	-	-
VESSEL	21	416	758	2015	10.79	0
YR	18	241	740	1775	7.29	0
VESSEL:YR	47	503	693	1272	5.83	0

Table 3. Reported landings and dead discards (mt) of blue shark in Canada, the Northwest Atlantic and the North Atlantic. In all but recent years, only landings were reported. Dead discards were reported only by certain countries, and even then, varied across years (i.e. Canada). Catch statistics from the Canadian Atlantic, Northwest Atlantic and North Atlantic were all derived from different sources, and therefore cannot be summed across columns. All values are rounded to the nearest tonne (mt).

Year	Canadian Atlantic (NAFO Areas 2-5)					Northwest Atlantic									North Atlantic
	CDN	FAR ISLES	JPN	Other	Total	JPN	USA	CDN	SPN	POR	BEL	PAN	Other	Unspecified Pelagic	
1979	-	-	4	0	4	-	-	-	-	-	-	-	-	-	12
1980	-	-	0	13	14	12638	-	-	-	-	-	-	-	-	-
1981	-	0	1	0	1	13280	204	-	-	-	-	-	-	-	204
1982	-	-	2	0	2	7258	0	-	-	-	-	-	-	-	9
1983	-	-	1	0	1	5632	605	-	-	-	-	-	-	-	613
1984	-	-	0	0	0	11939	107	-	-	-	-	-	-	-	121
1985	-	-	0	0	0	12803	341	-	-	-	-	-	-	-	380
1986	-	-	13	0	13	16427	1112	320	-	-	-	-	-	-	1482
1987	-	0	38	0	38	14948	1384	147	-	-	-	-	-	-	1638
1988	-	0	5	0	5	12306	767	968	-	-	-	-	-	-	1835
1989	-	0	10	0	10	12039	746	978	-	-	-	-	-	-	1810
1990	8	0	13	0	21	14397	822	680	-	-	-	-	-	-	3028
1991	31	4	5	0	40	13531	1076	774	-	-	-	-	-	-	4299
1992	101	30	30	0	161	13177	399	1277	-	-	-	-	-	-	3536
1993	24	28	46	0	98	9064	1813	1702	-	-	-	-	-	-	9566
1994	138	-	109	0	247	6147	594	1260	-	-	-	-	-	625	8090
1995	152	-	71		223	5728	639	1494	-	-	-	-	3	996	8293
1996	23	-	173		196	5603	963	528	-	-	-	-	14	275	7260
1997	19	-	36	0	55	3907	379	831	12315	-	-	-	1	1011	29201
1998	14	-	17		31	5039	444	612	12963	-	-	-	78	123	26571
1999	67	-	11	0	78	5697	316	547	12586	-	-	9	88	489	25761
2000	34	-	0		34	4413	428	624	14776	-	-	-	7	727	28010
2001	8	-	-	-	8	5504	145	581	9404	-	-	-	6	-	21069
2002	21	-	-	0	21	7484	68	836	8507	283	-	-	0	-	20053

Year	Canadian Atlantic (NAFO Areas 2-5)					Northwest Atlantic									North Atlantic
	CDN	FAR ISLES	JPN	Other	Total	JPN	USA	CDN	SPN	POR	BEL	PAN	Other	Unspecified Pelagic	
2003	18	-	-	-	18	5918	0	346	10269	48	-	-	3	-	22921
2004	11	-	-	-	11	4253	71	965	11223	1006	-	-	9	-	21865
2005	7	-	-	-	7	4356	68	1134	10568	2311	-	-	26	15	22429
2006	10	-	-	-	10	3515	47	977	12017	11	-	254	10	-	23394
2007	9	-	-	-	9	3317	54	843	12718	48	-	892	18	-	26976
2008	13	-	-	-	13	3789	137	0	14529	32	-	613	8	-	30803
2009	11	-	-	-	11	526	107	0	15491	942	114	1575	345	-	35381
2010	13	-	-	-	13	592	176	0	18330	195	461	-	138	-	37393
2011	9	-	-	-	9	1156	271	0	-	144	1039	-	673	-	38123
2012	14	-	-	-	14	747	162	1	-	211	903	-	588	-	36172
2013	10	-	-	-	10	-	-	-	-	-	-	-	-	-	-
2014	8	-	-	-	8	-	-	-	-	-	-	-	-	-	-

CDN = Canada; FAR ISLES = Faroe Islands; JPN = Japan; USA = United States; SPN = Spain; POR = Portugal; BEL = Belize; and PAN = Panama.

Notes:

1. Canada is from DFO Zonal Statistics File and shark derby statistics.
2. Japan, Faroes, other countries in Canadian Atlantic are from DFO Maritimes & Newfoundland and Labrador Observer programs (excludes discards).
3. NW Atlantic landings from countries other than Japan are from ICCAT statistics for area 92 until 1999.
4. Japan in NW Atlantic represents nominal catch of unspecified sharks and rays from FAO Statistics.
5. North Atlantic (plus Mediterranean) landings from ICCAT.

Table 4. Catch and discards (mt) of blue sharks in Canadian waters as observed by at-sea observers.

	Catch					Discards					Discard Percentage				
Year	CDN	FAR ISLES	JPN	Other	Total	CDN	FAR ISLES	JPN	Other	Total	CDN	FAR ISLES	JPN	Other	Total
1978	1	-	8	0	9	1	-	8	0	9	100	-	100	100	100
1979	10	-	13	0	23	10	-	8	0	19	100	-	67	100	82
1980	0	-	5	13	19	0	-	5	0	5		-	92	1	27
1981	0	0	13	0	14	0	0	12	0	12	100	100	90	100	91
1982	0	-	54	0	54	0	-	52	0	53	100	-	97	100	97
1983	0	-	26	0	26	0	-	25	0	26	100	-	97	67	97
1984	0	-	14	0	14	0	-	13	0	14	100	-	97	100	97
1985	1	-	0	0	1	1	-	0	0	1	100	-	100	100	100
1986	0	-	44	1	45	0	-	31	1	31		-	70	100	70
1987	0	1	158	0	160	0	1	121	0	122	100	100	76	100	76
1988	0	2	133	1	136	0	2	129	1	131	100	100	96	100	96
1989	42	2	173	0	218	42	2	163	0	208	100	100	94	100	95
1990	8	2	114	0	125	7	2	101	0	111	89	100	89	100	89
1991	23	46	134	19	221	20	41	129	19	208	84	90	96	100	94
1992	2	112	231	0	345	2	82	201	0	285	100	73	87	100	83
1993	15	35	231	0	282	14	8	185	0	207	96	22	80	58	74
1994	64	-	298	3	366	48	-	190	3	241	75	-	64	100	66
1995	122	-	168	-	290	107	-	97	-	204	88	-	58	-	70
1996	40	-	234	-	274	37	-	61	-	99	94	-	26	-	36
1997	30	-	36	0	67	30	-	0	0	30	98	-	0	100	45
1998	210	-	34	-	244	210	-	17	-	226	100	-	50	-	93
1999	186	-	292	0	478	185	-	282	0	467	99	-	96	-	98
2000	71	-	3	-	74	70	-	3	-	74	99	-	100	-	99
2001	179	-	-	-	179	179	-	-	-	179	100	-	-	-	100
2002	229	-	-	4	233	228	-	-	4	232	100	-	-	100	100
2003	85	-	-	-	85	85	-	-	-	85	100	-	-	-	100
2004	59	-	-	-	59	59	-	-	-	59	100	-	-	-	100
2005	60	-	-	-	60	57	-	-	-	57	94	-	-	-	94
2006	140	-	-	-	140	140	-	-	-	140	100	-	-	-	100
2007	81	-	-	-	81	80	-	-	-	80	100	-	-	-	100

	Catch					Discards					Discard Percentage				
Year	CDN	FAR ISLES	JPN	Other	Total	CDN	FAR ISLES	JPN	Other	Total	CDN	FAR ISLES	JPN	Other	Total
2008	93	-	-	-	93	93	-	-	-	93	100	-	-	-	100
2009	117	-	-	-	117	117	-	-	-	117	100	-	-	-	100
2010	282	-	-	-	282	282	-	-	-	282	100	-	-	-	100
2011	148	-	-	-	148	148	-	-	-	148	100	-	-	-	100
2012	163	-	-	-	163	162	-	-	-	162	100	-	-	-	100
2013	58	-	-	-	58	58	-	-	-	58	100	-	-	-	100
2014	64	-	-	-	64	64	-	-	-	64	100	-	-	-	100

CDN = Canada; FAR ISLES = Faroe Islands; and JPN = Japan.

Table 5. Estimation of blue shark bycatch discards (mt) in the Canadian pelagic longline fishery for tuna and swordfish, broken down by season (quartile).

Quartile	Estimate	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	Swordfish & Tuna Kept Catch from Maritimes Region At-Sea Observer Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-
	Blue Shark Discard Catch from Maritimes Region At-Sea Observer Program	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ratio of Blue Shark Discard to Swordfish & Tuna Kept Catch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Ratio of Mean Blue Shark Discard to Swordfish & Tuna Kept Catch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Swordfish & Tuna Catch from MARFIS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Estimated Discard of Blue Shark Catch in Swordfish & Tuna Fishery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Swordfish & Tuna Kept Catch from Maritimes Region At-Sea Observer Program	10.4	-	-	3.2	18.6	18.7	27.6	11.9	22.6	8.2	11.3	11.8	6.1	4.4	17.8	5.9	5.2	6.4	22.9
	Blue Shark Discard Catch from Maritimes Region At-Sea Observer Program	18.5	-	-	0.2	11.4	10.3	44.9	14.6	12.7	3.0	10.7	4.1	3.4	1.0	26.8	14.1	6.7	9.8	35.0
	Ratio of Blue Shark Discard to Swordfish & Tuna Kept Catch	1.78	-	-	0.08	0.62	0.55	1.63	1.23	0.56	0.36	0.94	0.35	0.56	0.23	1.51	2.4	1.3	1.5	1.5
	Ratio of Mean Blue Shark Discard to Swordfish & Tuna Kept Catch	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
	Swordfish & Tuna Catch from MARFIS	63	85	71	111	114	192	75	65	109	178	107	125	174	125	169	113	144	133	221
	Estimated Discard of Blue Shark Catch in Swordfish & Tuna Fishery	63	85	71	112	115	194	75	66	110	180	108	126	176	126	170	114	145	134	223
3	Swordfish & Tuna Kept Catch from Maritimes Region At-Sea Observer Program	35.5	100.5	82.4	50.7	23.5	115.7	301.4	122.2	50.2	85.1	85.1	81.4	73.1	113.7	101.9	112.5	135.2	32.3	40.8
	Blue Shark Discard Catch from Maritimes Region At-Sea Observer Program	12.7	22.4	152.9	27.6	34.8	66.3	110.3	63.6	32.7	48.7	37.8	67.3	68.4	84.0	141.1	81.7	101.7	36.0	54.7
	Ratio of Blue Shark Discard to Swordfish & Tuna Kept Catch	0.36	0.22	1.86	0.54	1.48	0.57	0.37	0.52	0.65	0.57	0.44	0.83	0.94	0.74	1.38	0.7	0.8	1.1	1.3

Quartile	Estimate	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Ratio of Mean Blue Shark Discard to Swordfish & Tuna Kept Catch	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	Swordfish & Tuna Catch from MARFIS	731	1022	784	879	823	860	1017	976	1243	1488	1426	1284	1151	1046	1170	1197	1358	1085	1207
	Estimated Discard of Blue Shark Catch in Swordfish & Tuna Fishery	593	829	636	713	668	697	825	792	1008	1206	1156	1041	933	848	948	970	1101	880	979
4	Swordfish & Tuna Kept Catch from Maritimes Region At-Sea Observer Program	1.5	3.9	13.4	73.8	23.3	40.6	91.5	16.1	2.8	0.9	61.0	6.6	4.0	7.6	41.9	45.2	54.9	27.1	41.8
	Blue Shark Discard Catch from Maritimes Region At-Sea Observer Program	0.0	0.2	55.3	154.1	21.1	89.8	67.4	5.7	12.5	4.5	90.9	7.8	18.1	18.7	112.7	50.5	50.9	7.5	17.8
	Ratio of Blue Shark Discard to Swordfish & Tuna Kept Catch	0.00	0.05	4.14	2.09	0.91	2.21	0.74	0.35	4.40	5.02	1.49	1.18	4.56	2.46	2.69	1.1	0.9	0.3	0.4
	Ratio of Mean Blue Shark Discard to Swordfish & Tuna Kept Catch	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84
	Swordfish & Tuna Catch from MARFIS	94	104	120	74	41	38	152	227	204	185	191	148	127	104	170	282	217	368	262
	Estimated Discard of Blue Shark Catch in Swordfish & Tuna Fishery	173	191	221	136	76	71	281	419	376	341	351	273	235	191	313	520	400	679	483

MARFIS = Maritimes Fisheries Information System database, DFO Maritimes Region.

Table 6. Total and fishery-specific estimated discards (mt) and mortality of blue sharks in DFO Maritimes Region. DFO Newfoundland and Labrador Region discards (average less than 20 mt per year) are not shown.

Source	Discards (mt)																		
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Estimated Total Catch	861	1145	962	992	890	992	1207	1300	1517	1753	1643	1467	1372	1189	1457	1622	1662	1705	1699
Estimated Total Discards	852	1133	955	985	881	985	1202	1296	1512	1745	1637	1461	1365	1184	1451	1618	1657	1700	1692
Hooking and Post-release Mortality	196	260	220	227	203	227	277	298	348	401	376	336	314	272	334	372	381	391	389
Commercial Landings	9	5	2	52	18	0	2	6	0	0	0	0	0	0	0	0	0	0	0
Fishery	**Discards (mt)**																		
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Swordfish and Tuna Longline	828	1105	929	960	858	962	1181	1276	1494	1727	1615	1440	1343	1165	1431	1604	1646	1692	1684
Porbeagle Longline	3	4	3	4	3	2	1	0	1	1	1	0	1	0	0	0	0	0	0
Groundfish Longline	19	22	21	20	19	19	19	19	16	17	20	20	20	17	19	12	10	7	7
Groundfish Gillnet	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Groundfish Otter Trawl	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Total	852	1133	955	985	881	985	1202	1296	1512	1745	1637	1461	1365	1184	1451	1618	1657	1700	1692

Table 7. Observed blue shark condition upon release from Canadian pelagic longline.

Condition After Release	2010	2011	2012	2013	2014	Total
Unable to Determine	392	774	652	609	1751	4178
Alive - No Injury	3513	3712	1759	301	98	9383
Alive - Injured	1779	475	1563	71	32	3920
Dead	824	504	665	57	60	2110
Shark Bit - Not Intact	9	5	21	0	1	36
Moribund	10	33	75	10	15	143
Total	6527	5503	4735	1048	1957	19770

Table 8. Number and weight per shark species landed at shark derbies between 1993-2014. Weights are live equivalent weights.

Year	Blue shark		Mako		Porbeagle		Thresher shark		Total	
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)
1993	93	3636	-	-	1	6	-	-	94	3642
1994	117	5048	-	-	-	-	-	-	117	5048
1995	122	6464	-	-	-	-	-	-	122	6464
1996	114	4967	1	46	-	-	-	-	115	5013
1997	273	10315	-	-	-	-	-	-	273	10315
1998	269	10406	-	-	-	-	-	-	269	10406
1999	300	14598	-	-	-	-	-	-	300	14598
2000	235	15488	3	489	-	-	-	-	238	15977
2001	162	7594	-	-	1	57	1	84	164	7735
2002	327	19324	4	674	1	27	-	-	332	20026
2003	342	12016	3	399	1	132	-	-	346	12548
2004	257	10283	6	996	-	-	-	-	263	11279
2005	129	6276	2	390	3	370	1	123	135	7159
2006	98	10018	5	392	7	536	1	183	111	11130
2007	89	8358	3	201	-	-	-	-	92	8559
2008	144	13134	-	-	-	-	2	312	146	13446
2009	103	10456	3	492	-	-	-	-	106	10948
2010	121	12418	3	250	-	-	-	-	124	12668
2011	97	8980	2	153	1	130	-	-	100	9263
2012	162	12994	5	422	-	-	-	-	167	13417
2013	114	9752	2	324	-	-	-	-	116	10077
2014	106	7855	3	428	-	-	-	-	109	8283

Table 9a. Number of recreational domestic blue sharks tagged in Canadian waters and subsequently recaptured

Year Tagged	Number Tagged	Year Recaptured									Total
		2006	2007	2008	2009	2010	2011	2012	2013	2014	
2006	179	4	1	-	-	-	-	-	-	-	5
2007	167	-	-	-	-	-	-	-	-	-	0
2008	130	-	-	-	-	-	-	-	-	-	0
2009	134	-	-	-	-	-	-	-	-	-	0
2010	324	-	-	-	-	2	1	-	-	-	3
2011	312	-	-	-	-	-	1	-	1	-	2
2012	346	-	-	-	-	-	-	-	2	-	2
2013	471	-	-	-	-	-	-	-	1	-	1
2014	307	-	-	-	-	-	-	-	-	-	0
Unknown	4	-	-	-	-	-	-	-	-	-	0
Total	2374	4	1	-	-	2	2	-	4	-	13

Table 9b. Number of foreign and domestic blue sharks tagged in Canadian waters and subsequently recaptured

Year Tagged	Number Tagged	Year Recaptured									Total
		2006	2007	2008	2009	2010	2011	2012	2013	2014	
2006	179	4	8	-	1	-	-	-	-	-	13
2007	167	-	2	5	1	-	-	-	-	-	8
2008	130	-	-	-	2	1	1	-	1	-	5
2009	134	-	-	-	-	4	1	-	-	-	5
2010	324	-	-	-	-	2	4	1	-	-	7
2011	312	-	-	-	-	-	1	2	2	-	5
2012	346	-	-	-	-	-	-	-	4	-	4
2013	471	-	-	-	-	-	-	-	1	1	2
2014	307	-	-	-	-	-	-	-	-	1	1
Unknown	4	-	-	1	1	-	-	-	1	1	4
Total	2374	4	10	6	5	7	7	3	9	3	54

Table 10. Exploitation rates and Fishing Mortality (F) from recreational inshore angling and commercial offshore foreign longlining, based on Petersen estimates of a mark-recapture program.

Fishery	Year	Tagged	Recovered	Exploitation Rate	F
Domestic Recreational	2006	179	3	0.023	0.024
Domestic Recreational	2007	167	0	0.000	0.000
Domestic Recreational	2008	130	0	0.000	0.000
Domestic Recreational	2009	134	0	0.000	0.000
Domestic Recreational	2010	324	0	0.000	0.000
Domestic Recreational	2011	312	1	0.004	0.004
Domestic Recreational	2012	345	0	0.000	0.000
Domestic Recreational	2013	471	0	0.000	0.000
Domestic Recreational	2014	307	0	0.000	0.000
Domestic Commercial	2006	179	2	0.016	0.016
Domestic Commercial	2007	167	0	0.000	0.000
Domestic Commercial	2008	130	0	0.000	0.000
Domestic Commercial	2009	134	0	0.000	0.000
Domestic Commercial	2010	324	2	0.009	0.009
Domestic Commercial	2011	312	0	0.000	0.000
Domestic Commercial	2012	345	1	0.004	0.004
Domestic Commercial	2013	471	1	0.003	0.003
Domestic Commercial	2014	307	0	0.000	0.000
US Recreational	2006	179	1	0.008	0.008
US Recreational	2007	167	2	0.017	0.017
US Recreational	2008	130	0	0.000	0.000
US Recreational	2009	134	0	0.000	0.000
US Recreational	2010	324	0	0.000	0.000
US Recreational	2011	312	0	0.000	0.000
US Recreational	2012	345	0	0.000	0.000
US Recreational	2013	471	1	0.003	0.003
US Recreational	2014	307	0	0.000	0.000
Foreign Commercial	2006	179	3	0.023	0.024
Foreign Commercial	2007	167	4	0.033	0.034
Foreign Commercial	2008	130	1	0.011	0.011
Foreign Commercial	2009	134	3	0.031	0.032
Foreign Commercial	2010	324	3	0.013	0.013
Foreign Commercial	2011	312	1	0.004	0.004
Foreign Commercial	2012	345	0	0.000	0.000
Foreign Commercial	2013	471	0	0.000	0.000
Foreign Commercial	2014	307	0	0.000	0.000

Table 11. Total blue shark catch (mt) in Atlantic Canada by source. A dash (-) indicates that there is no recorded catch.

Year	Derbies	Recreational[1]	Landed Commercial[2]	Observed Foreign Catch[3]	Observed Foreign Discards‡	Estimated Catch and Discards from Canadian Fishery*	Total Estimated Catch Morality**
1986	-	-	-	13	32	801	446
1987	-	-	-	38	123	367	345
1988	-	-	-	6	146	2429	1367
1989	-	-	-	10	172	2446	1405
1990	-	-	8	13	125	1732	1012
1991	-	-	31	11	207	1857	1178
1992	-	-	101	60	285	2940	1916
1993	4	3	21	91	205	4255	2449
1994	5	3	144	116	210	3118	1031
1995	6	4	171	73	100	3506	1080
1996	5	3	20	173	61	852	408
1997	10	7	9	36	0	1136	317
1998	10	7	4	17	17	967	258
1999	15	10	53	11	282	987	372
2000	16	11	19	0	3	881	240
2001	8	13	0	0	0	985	236
2002	19	13	8	0	4	1219	310
2003	12	13	0	-	-	1314	315
2004	10	7	0	-	-	1512	359
2005	6	4	11	-	-	1762	423
2006	10	10	0	-	-	1644	389
2007	8	8	1	-	-	1470	348
2008	13	13	0	-	-	1370	330
2009	10	10	0	-	-	1189	285
2010	12	12	0	-	-	1462	350
2011	9	9	0	-	-	1638	387
2012	13	13	0	-	-	1678	400
2013	10	10	0	-	-	1700	402
2014	8	8	0	-	-	1692	398

[1] Catch and release fishery, excluding derbies; 2001-2005 estimated from rec logs and phone survey:
- before 2001 assumed to be 0.66 of derby catches based on tag recaptures and 2002-2003 ratios.
- 2006+ assumed to be equal to derby catches based on recent tag recaptures.

[2] Canadian landings only; Maritimes, Newfoundland and Labrador.

[3] Maritimes Region At-Sea Observer Program estimates of all foreign kept catch.

‡ Maritimes Region At-Sea Observer Program estimates of all foreign discarded catch.

* Taken from Table 6 and Figure 12; sum of estimated bycatch from all Canadian fisheries.

** Sum of landed catches, plus hooking and post-release mortality from Canadian fisheries:
- foreign discards prior to 1994 assumed to be dead due to finning.

FIGURES

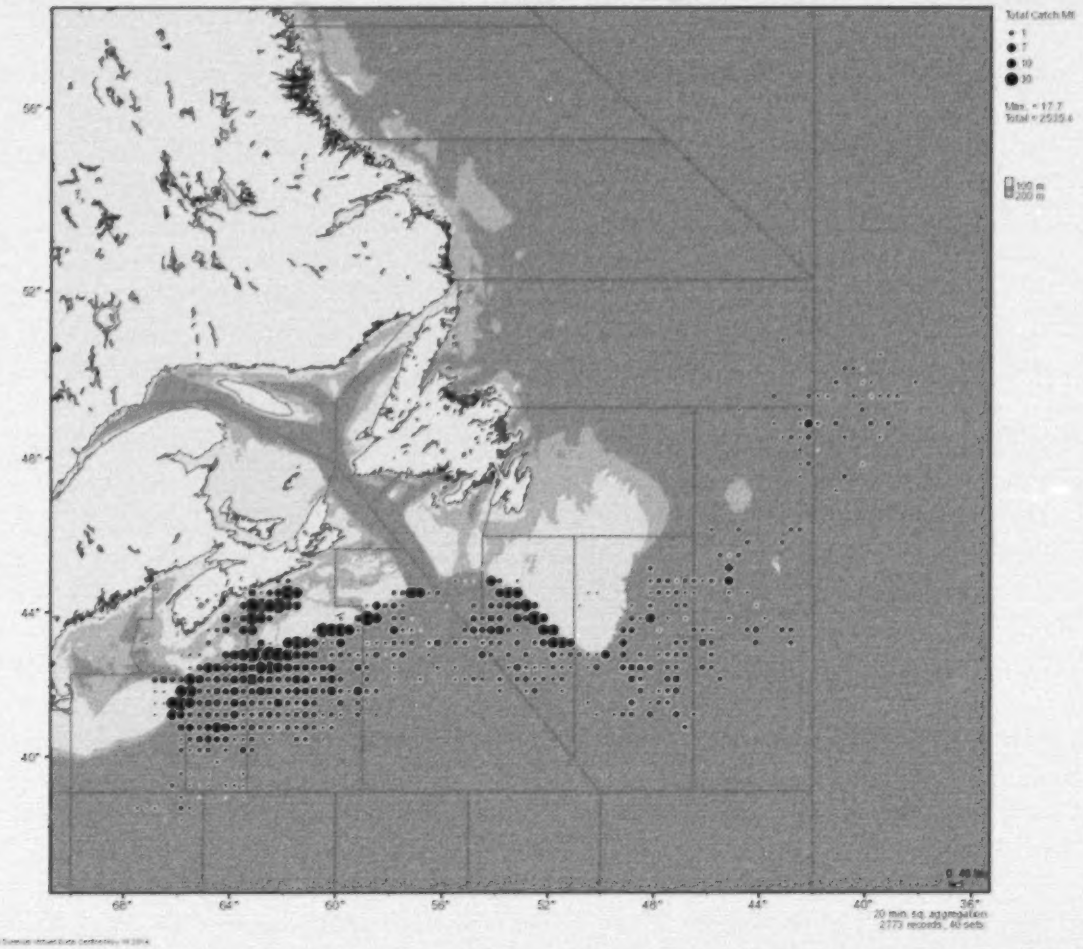


Figure 1. Observed blue shark catch locations onboard all commercial fishing vessels between 1998 and 2014 as observed by at-sea fishery observers operating in the DFO Maritimes Region.

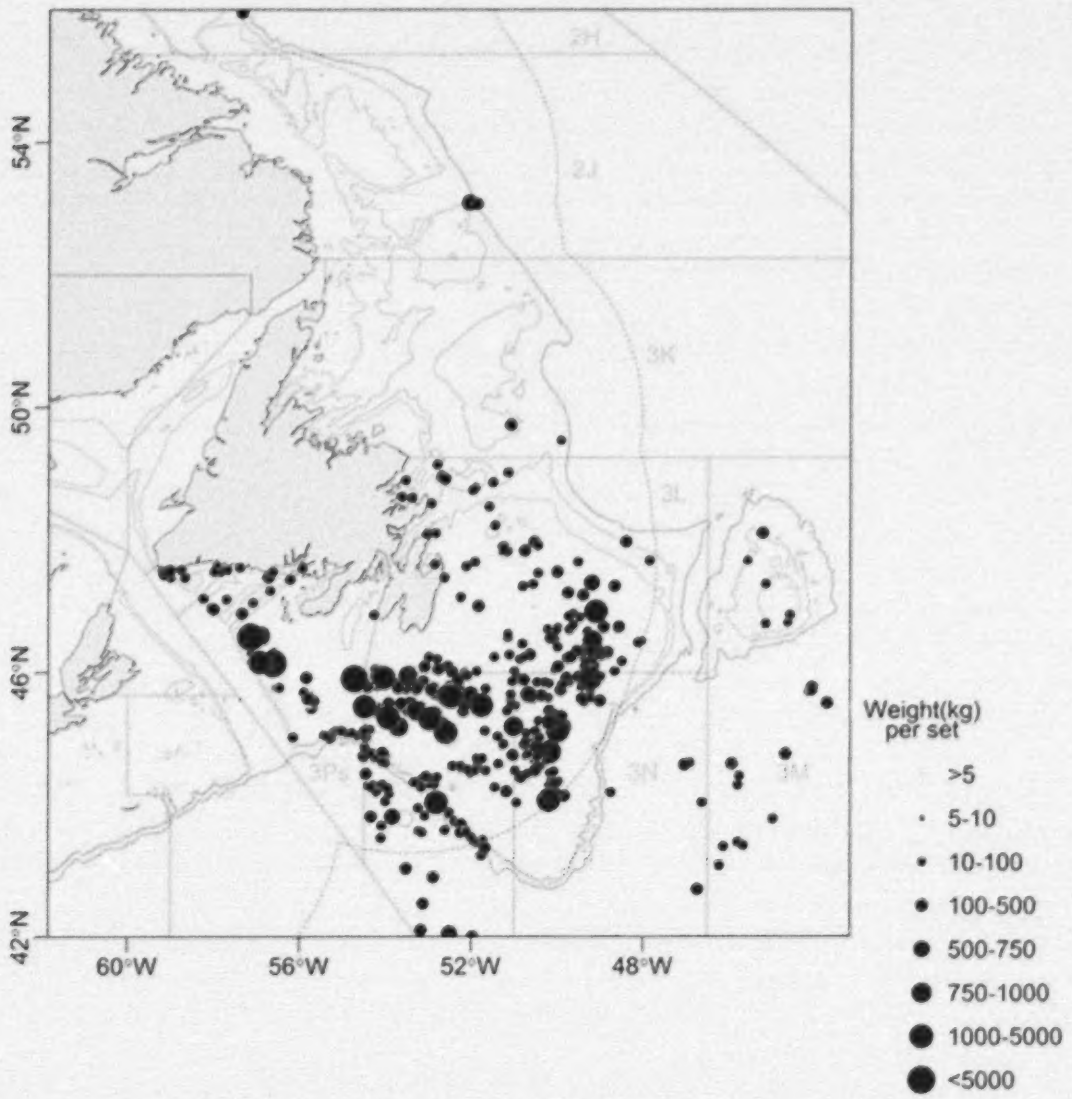


Figure 2. Blue shark commercial catch locations between 1980 and 2012 as recorded by at-sea fishery observers operating in the DFO Newfoundland and Labrador Region.

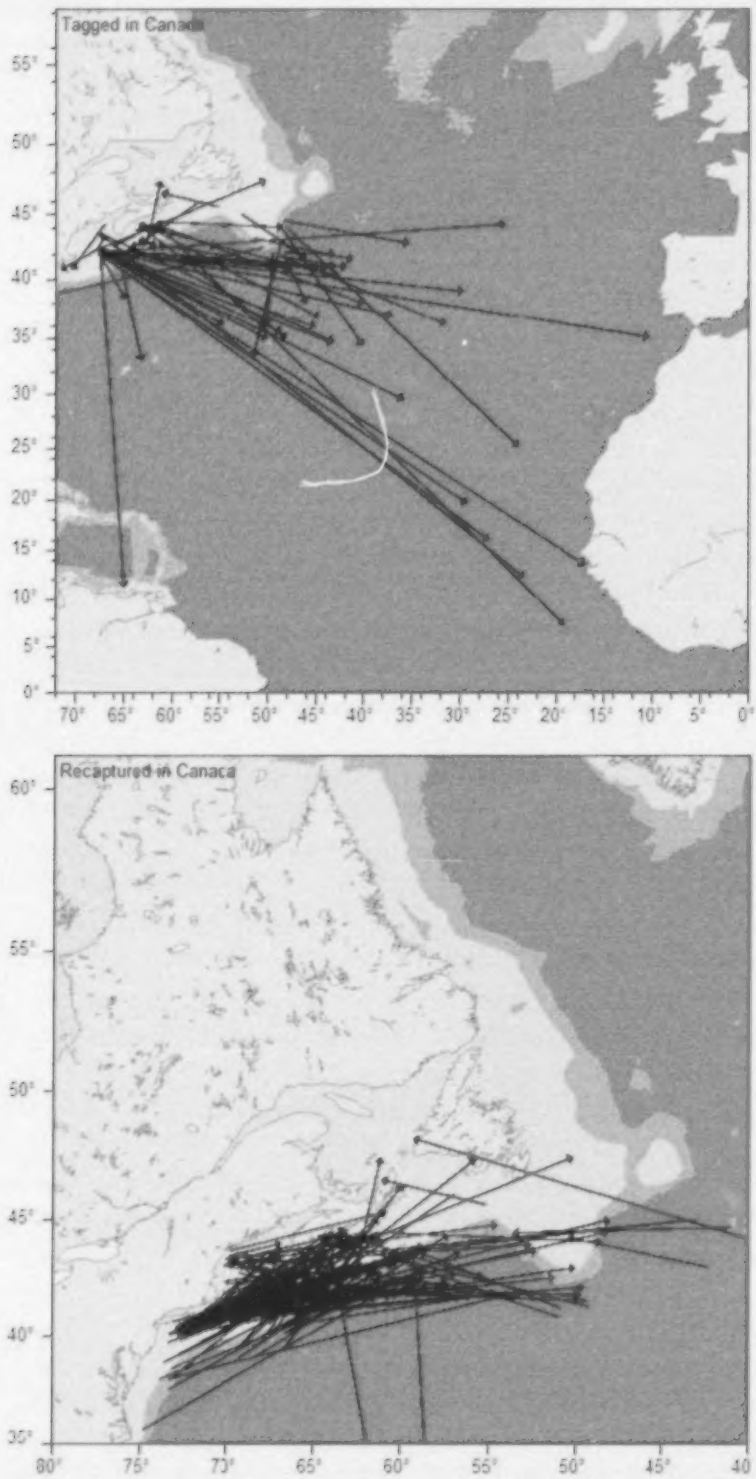


Figure 3. Blue sharks tagged or recaptured between 1971 and 2002 in Canadian waters under the U.S. National Marine Fisheries Service (NMFS) tagging program.

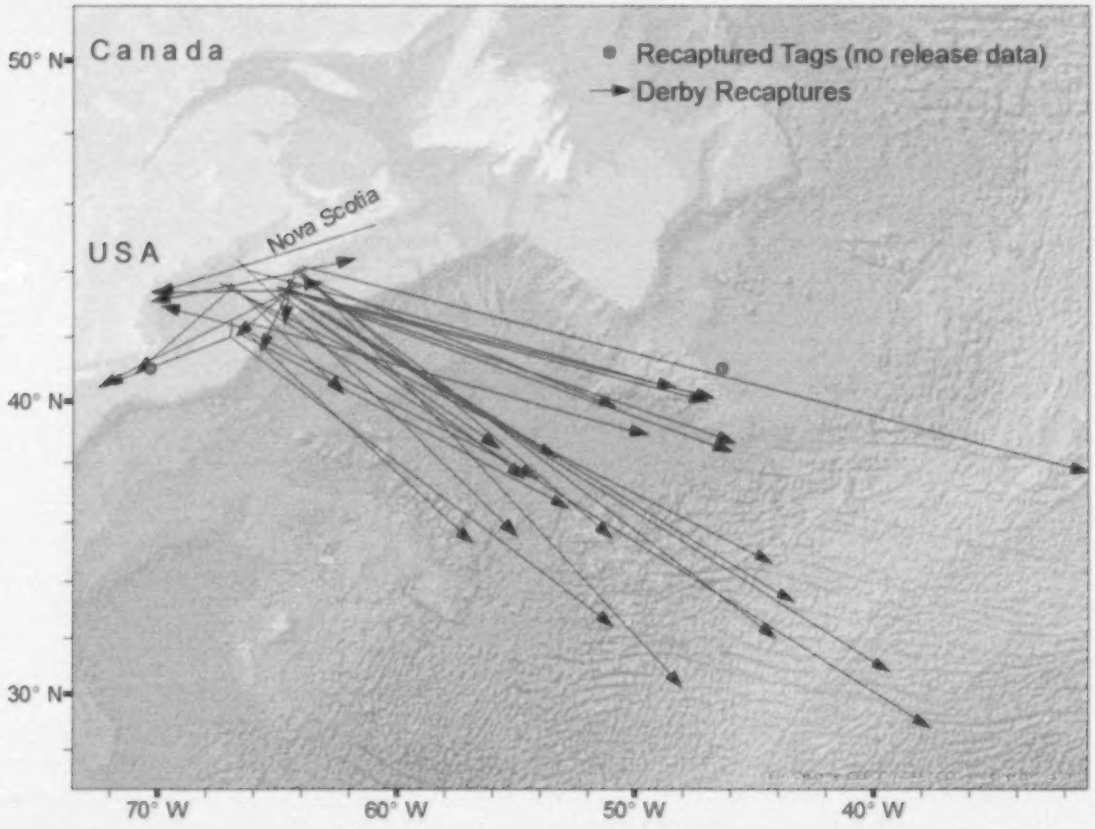


Figure 4. Recaptures of blue sharks tagged between 2006 and 2014 in Nova Scotia shark derbies.

Figure 5. Blue shark pop-up satellite archival tags (PSAT) tagging and pop-up locations as shown in Campana et al. (2011). Map shows tagging (⊛) and pop-up (●) locations for 23 blue sharks tagged off the eastern coast of Canada between 2003 and 2007. Pop-up symbols are coloured to match the corresponding tagging symbol. Month of pop-up indicated by number.

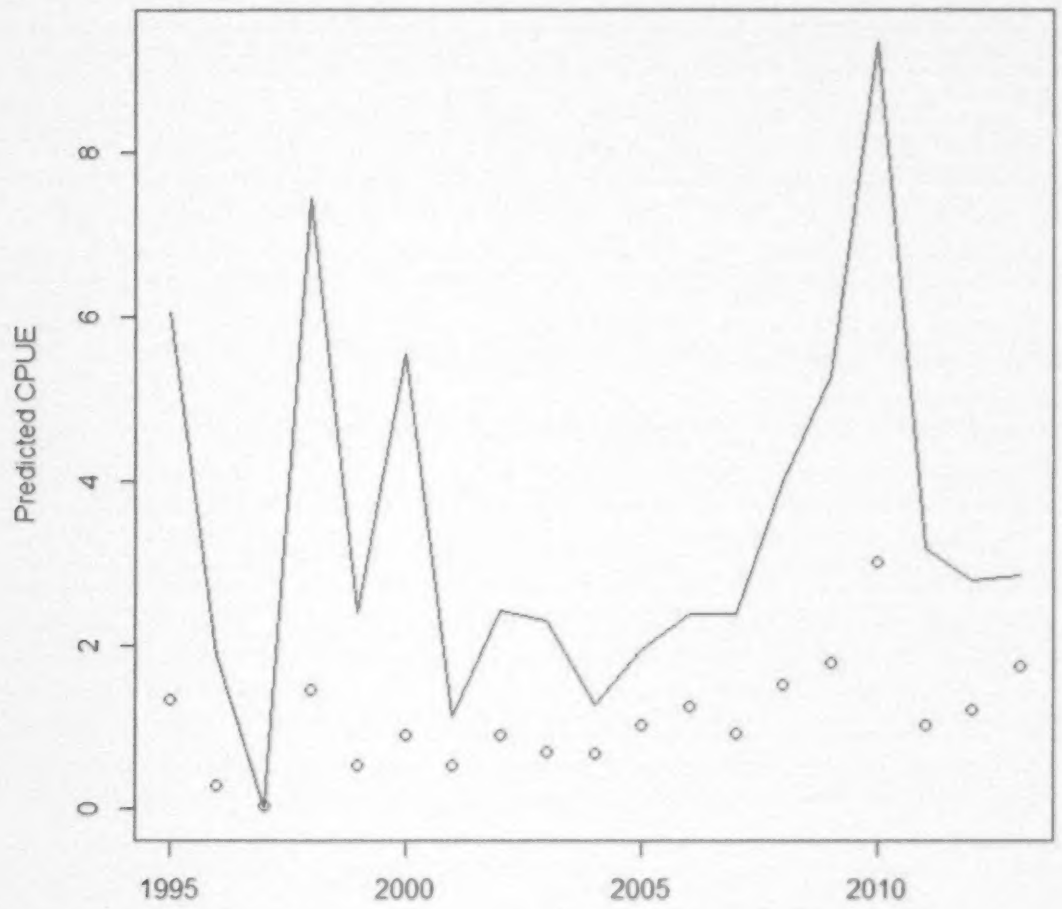


Figure 6. Predicted (line) and observed (open circles) generalized linear model (GLM) catch rate index (kg/hook) for blue sharks caught and observed in the June-October Swordfish fishery from 1995 to 2013.

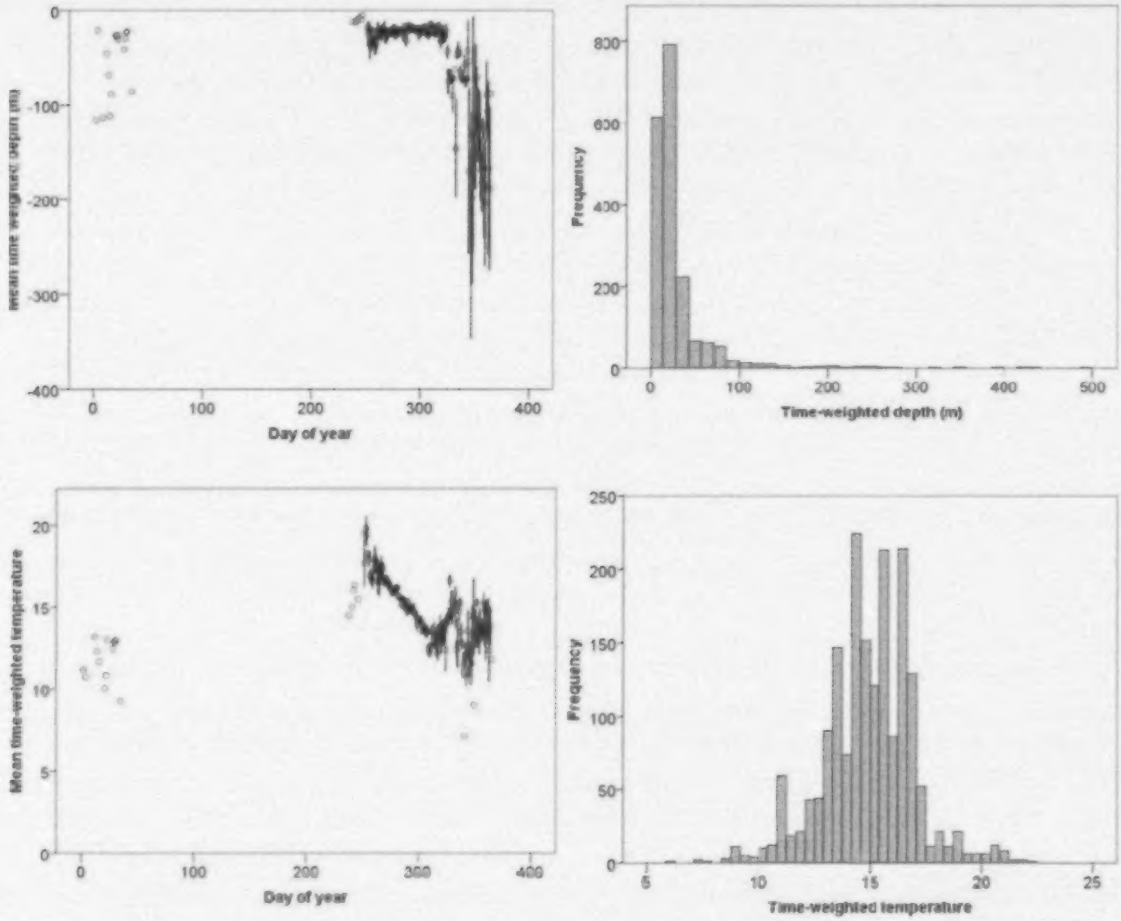


Figure 7. Depth (top panels) and temperature (°C) (bottom panels) occupied by blue sharks while in Canadian coastal waters as recorded by pop-up satellite archival tags (PSAT) tags. Bars represent mean ± 1 SE.

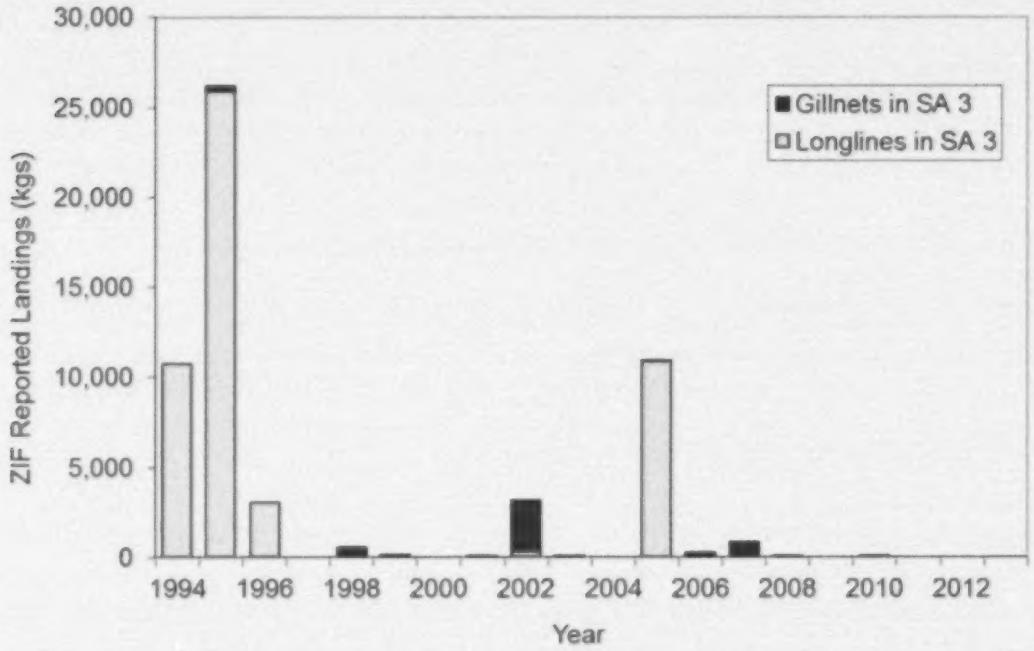


Figure 8. Total DFO Newfoundland and Labrador Region Zonal Interchange File Format (ZIFF) landings (kg) for blue shark, by gear type (gillnets or longlines), in NAFO Divisions 3LNO and NAFO Subdivision 3Ps.

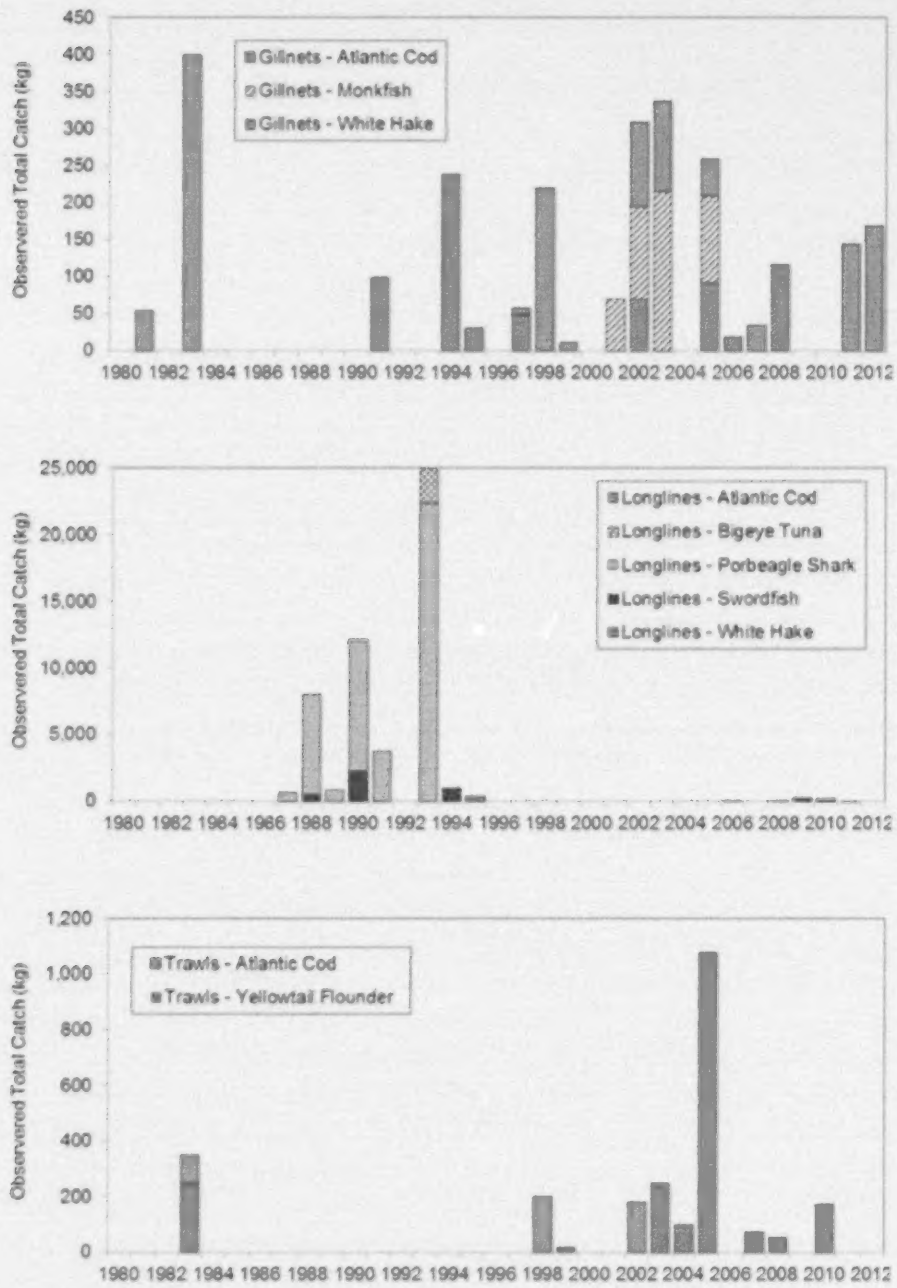

Observered Total Catch (kg)
Gillnets - Atlantic Cod
Gillnets - Monkfish
Gillnets - White Hake
Longlines - Atlantic Cod
Longlines - Bigeye Tuna
Longlines - Porbeagle Shark
Longlines - Swordfish
Longlines - White Hake
Trawls - Atlantic Cod
Trawls - Yellowtail Flounder
1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012

Figure 9. DFO Newfoundland and Labrador Region At-Sea Observer Program observed catch (kg) of blue shark by fishery in NAFO Divisions 3LNO and NAFO Subdivision 3Ps from 1980-2012.

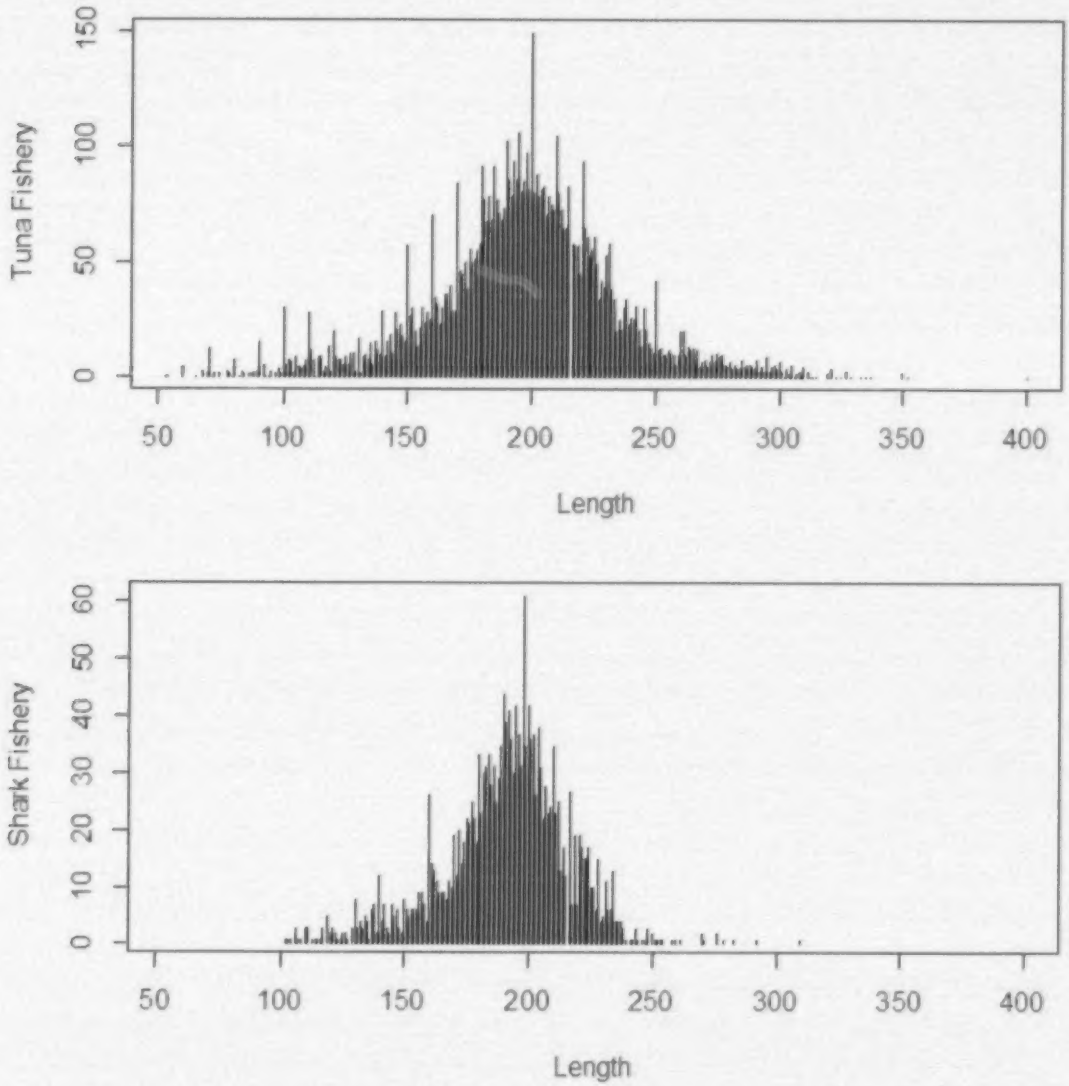


Figure 10. Length frequency (cm) of blue sharks in the swordfish/tuna (top panel) and directed shark (Porbeagle) (bottom panel) longline fisheries, based on Observer data from the DFO Maritimes Region.

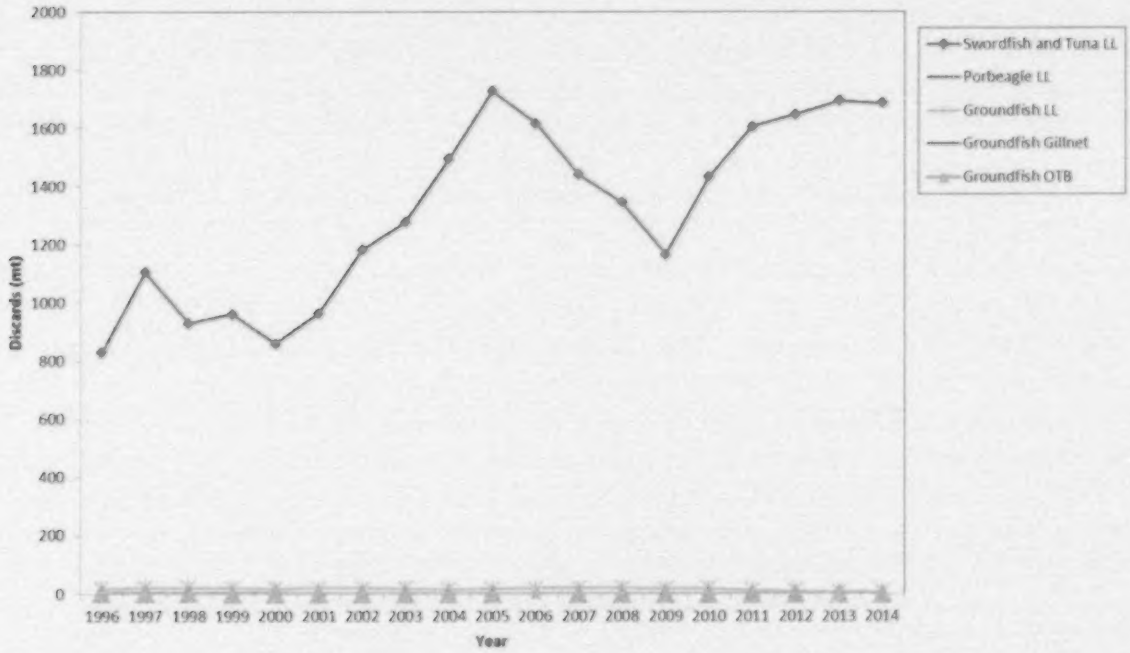


Figure 11. Estimated total Canadian blue shark discards (mt) by fishery from 1996-2014.

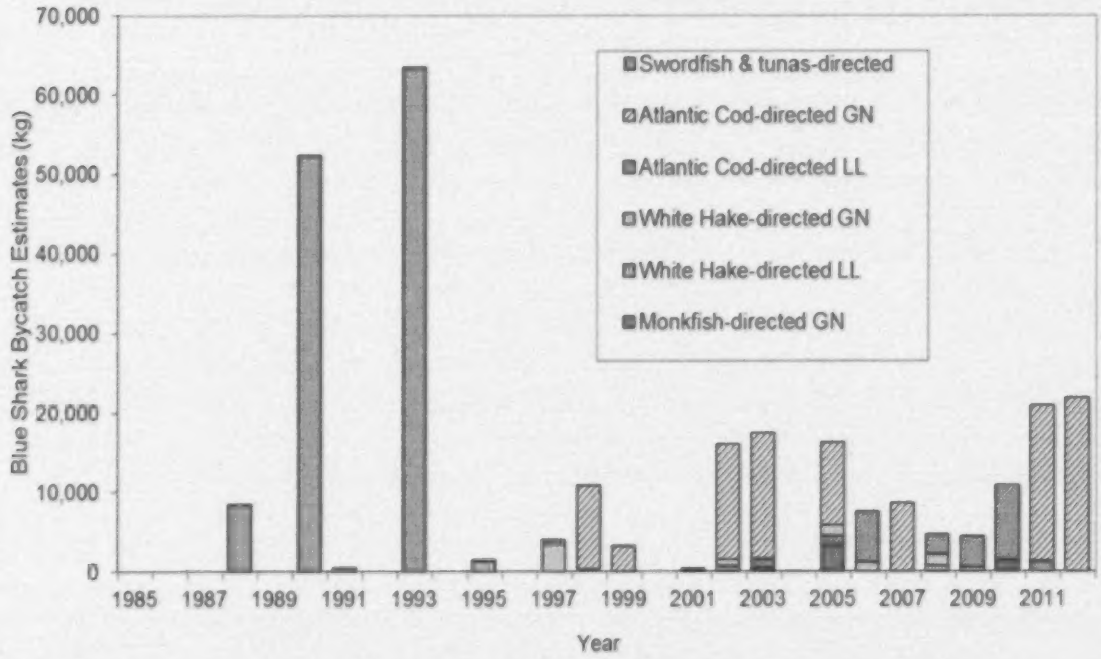


Figure 12. Estimated total catch (mt) of blue shark in NAFO Divisions 3LNO and NAFO Subdivision 3Ps from 1988 to 2012. Observed bycatch was pro-rated by total landings. Catch is plotted by directed species and gear type (GN=gillnet, LL=longline).

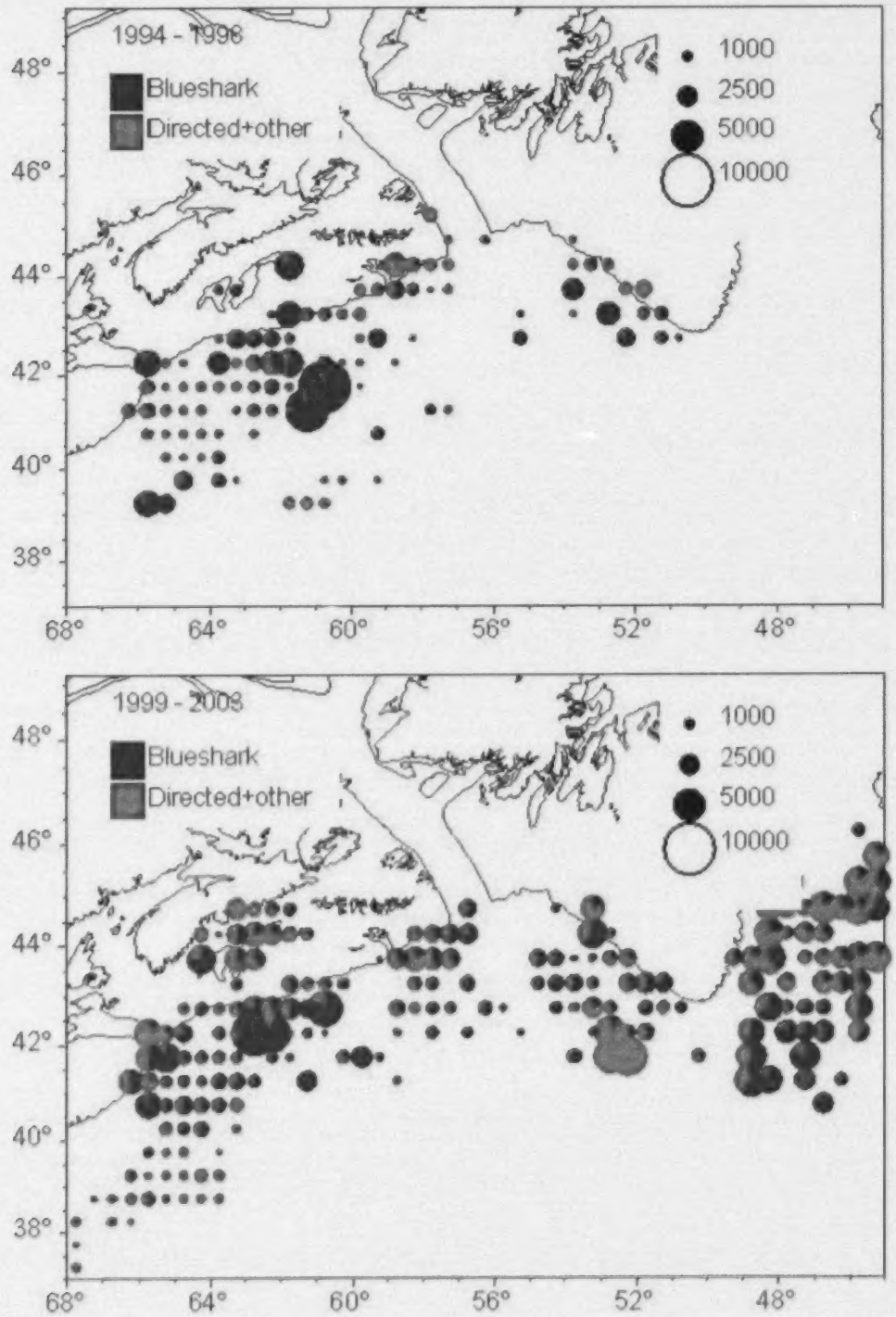


Figure 13a. Observed blue shark catch proportions in the Canadian large pelagic longline fishery, aggregated in 5-year blocks. Symbol size indicates the mean catch weight (kg) of all target and major bycatch species.

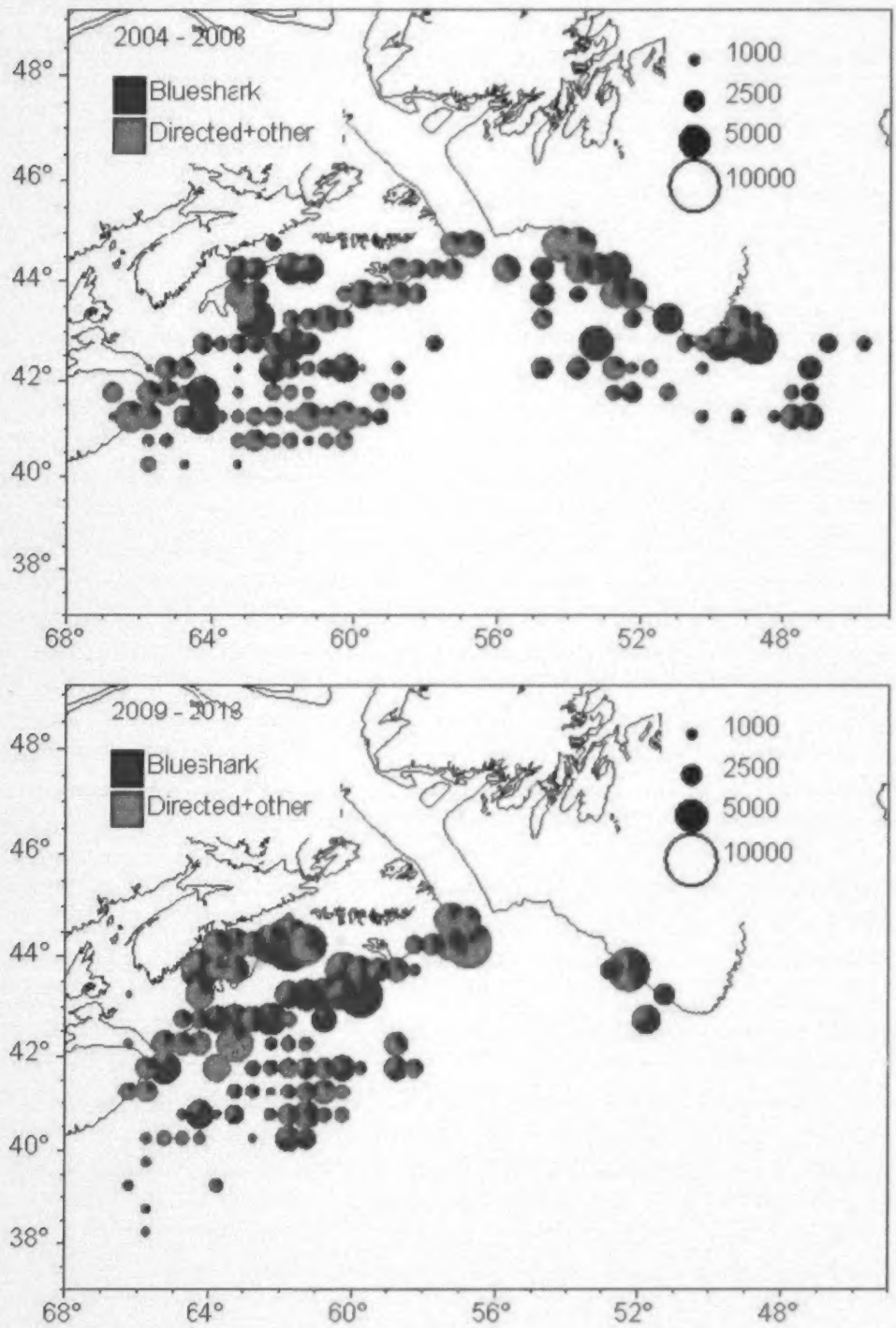


Figure 13b. Observed blue shark catch proportions in the Canadian large pelagic longline fishery, aggregated in 5-year blocks. Symbol size indicates the mean catch weight (kg) of all target and major bycatch species.

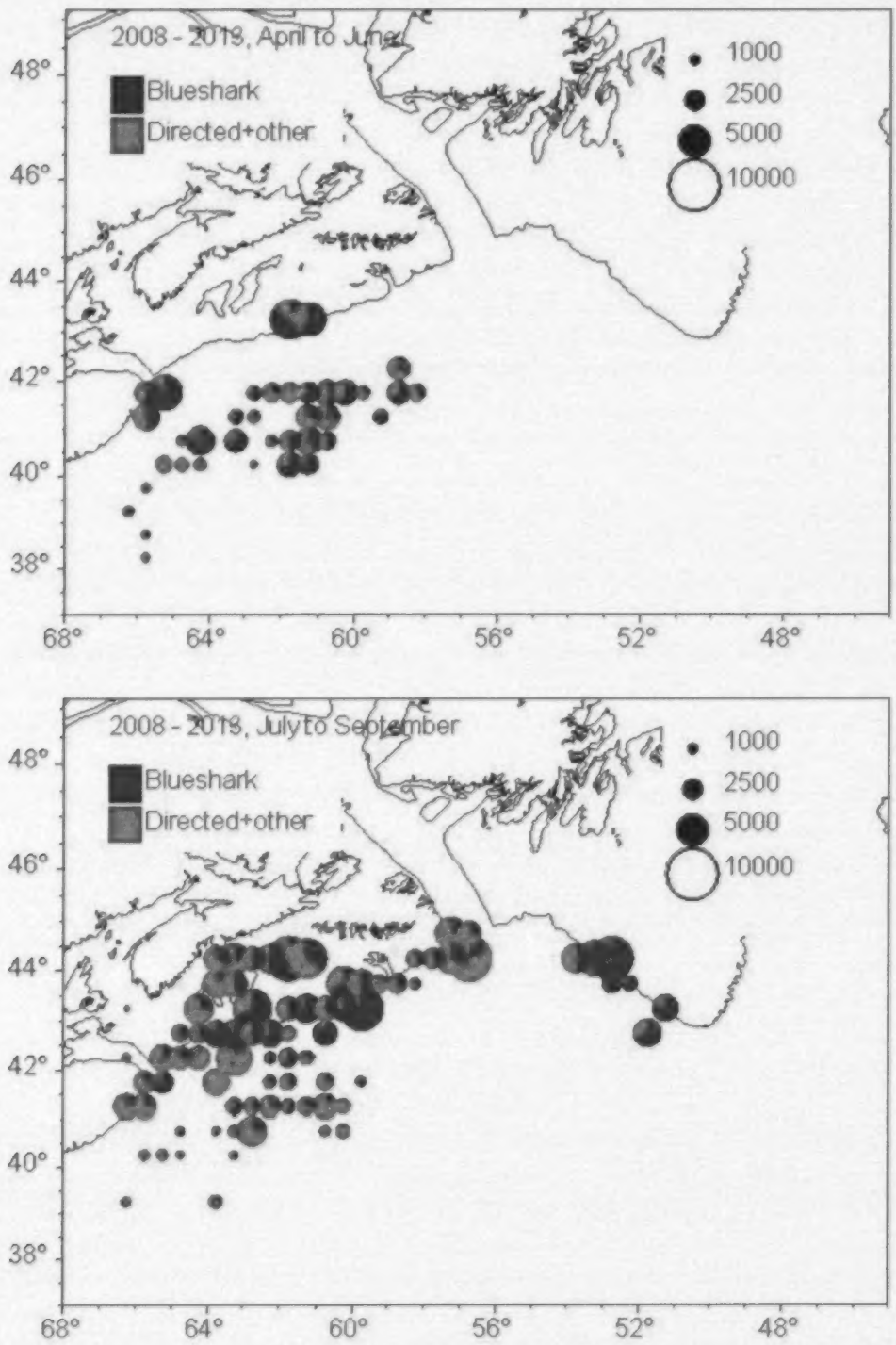


Figure 14a. Observed blue shark catch proportions in the 2008-2013 Canadian large pelagic longline fishery, aggregated by season. Symbol size indicates the mean catch weight (kg) of all target and major bycatch species.

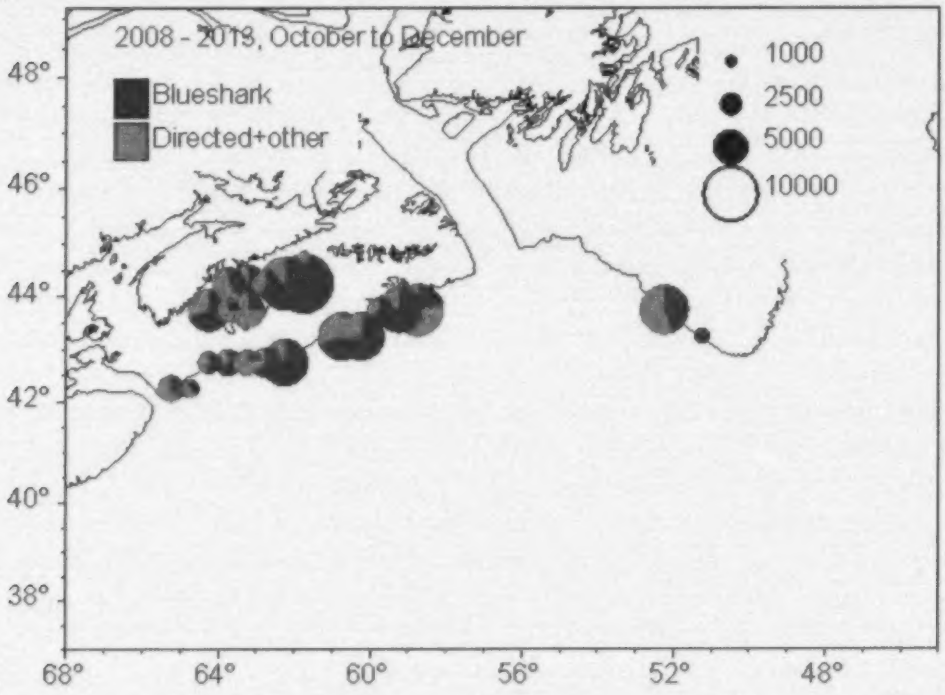


Figure 14b. Observed blue shark catch proportions in the 2008-2013 large pelagic longline fishery, aggregated by season. Symbol size indicates the mean catch weight (kg) of all target and major bycatch species.

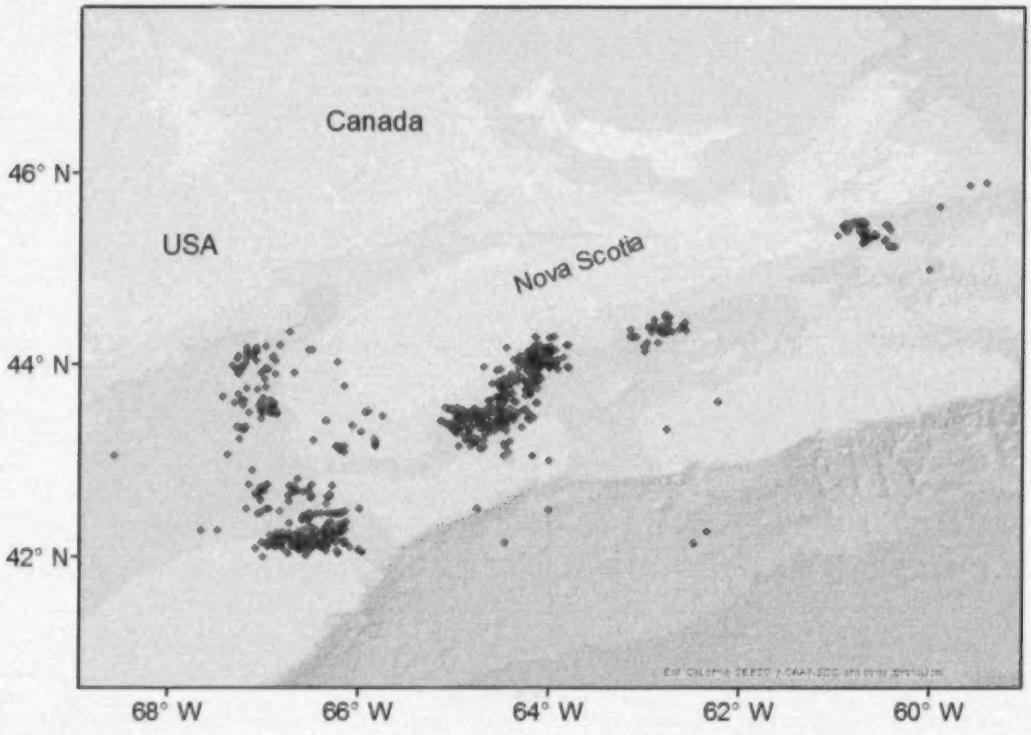
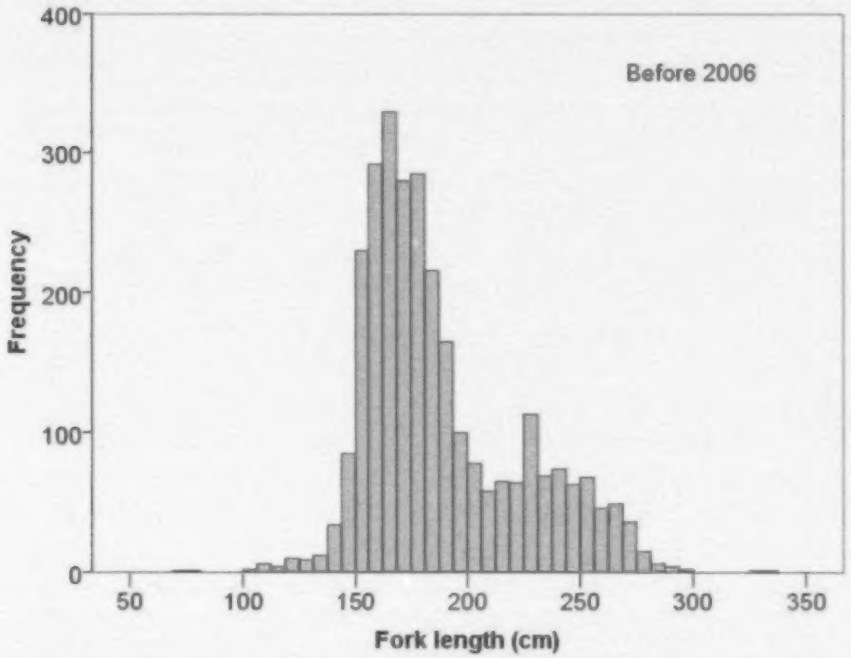


Figure 15. Reported fishing locations by participants at shark fishing derbies in Nova Scotia since 2000.



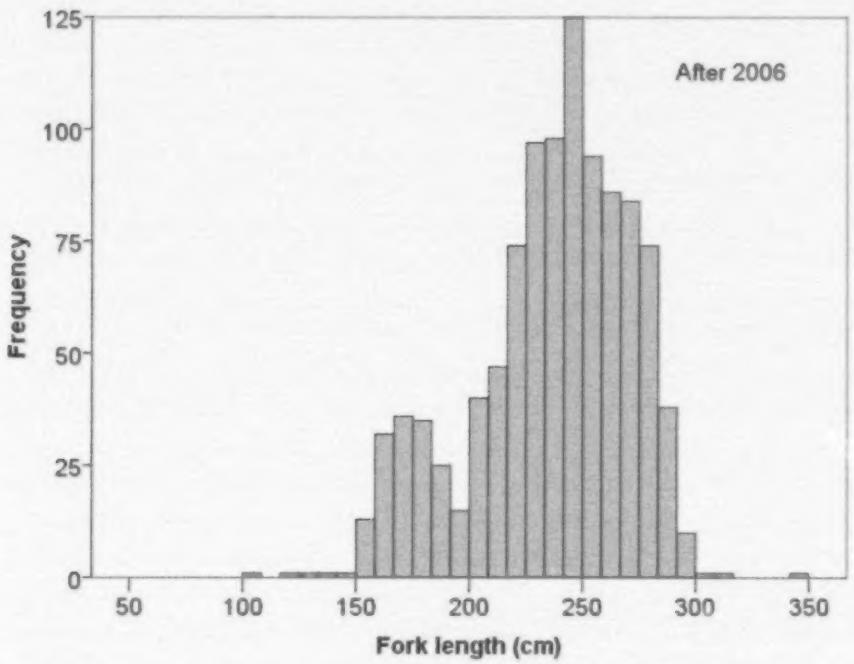


Figure 16. Length distribution (cm) of blue sharks landed at shark derbies before and after 2006, the year that minimum landing size was increased.

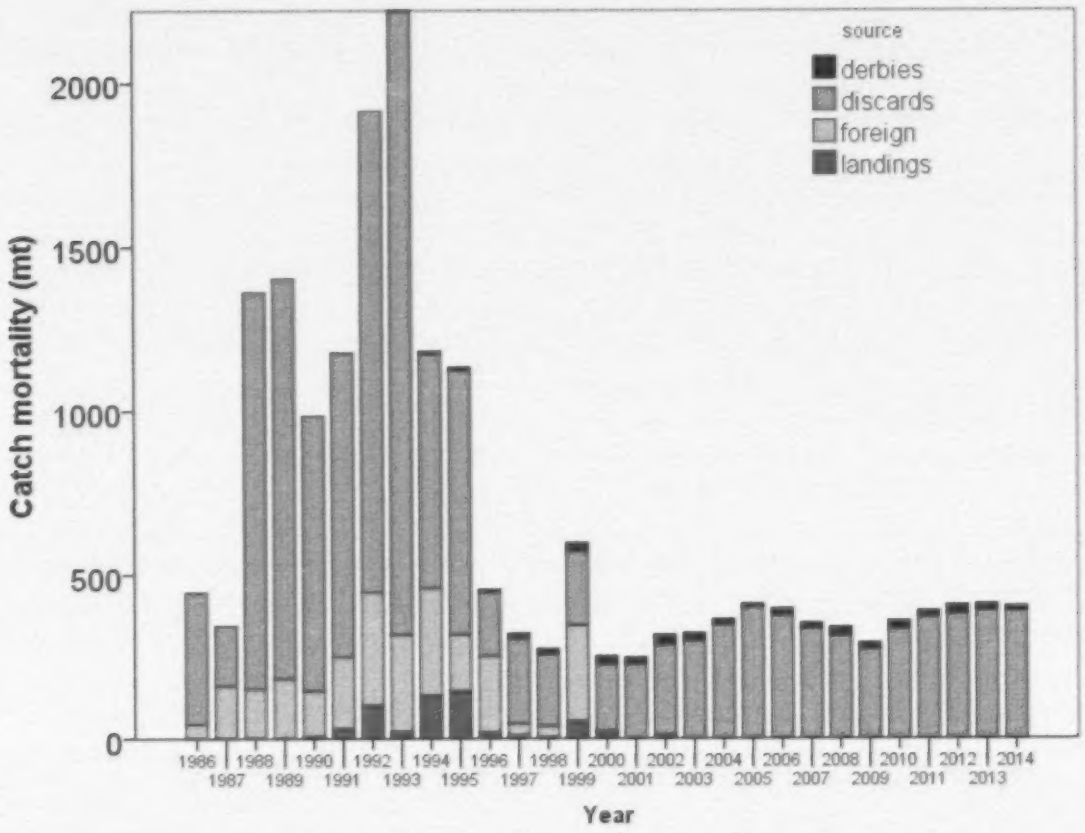


Figure 17. Total catch mortality (mt) by source for blue sharks caught in Canadian waters from 1996-2014.